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ARRL COMMITTEE ON AMATEUR RADIO DIGITAL COMMUNICATIONS

1524 Springvale Avenue
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January 11, 1983

Dr. Henry S. Magnuski KA6M
311 Stanford Ave
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TO : Members, ARRL Committee on
Amateur Radio Digital Communications

SUBJECT: Review of 1983 Radio Amateur's Handbook

The 1983 Handbook needs to be looked at now for changes that should go into the 1984 edition. I am enclosing a photocopy of pages 14-42 through 14-49 which cover RTTY and packet radio. It is obvious that a number of changes will be necessary, certainly updates to reflect the newly agreed Level 2 protocol and availability of additional packet equipment beyond the VADCG TNC. Also, if you have a copy of the 1983 edition, it might be helpful for you to look it over for possible improvements in any of the digital topics.

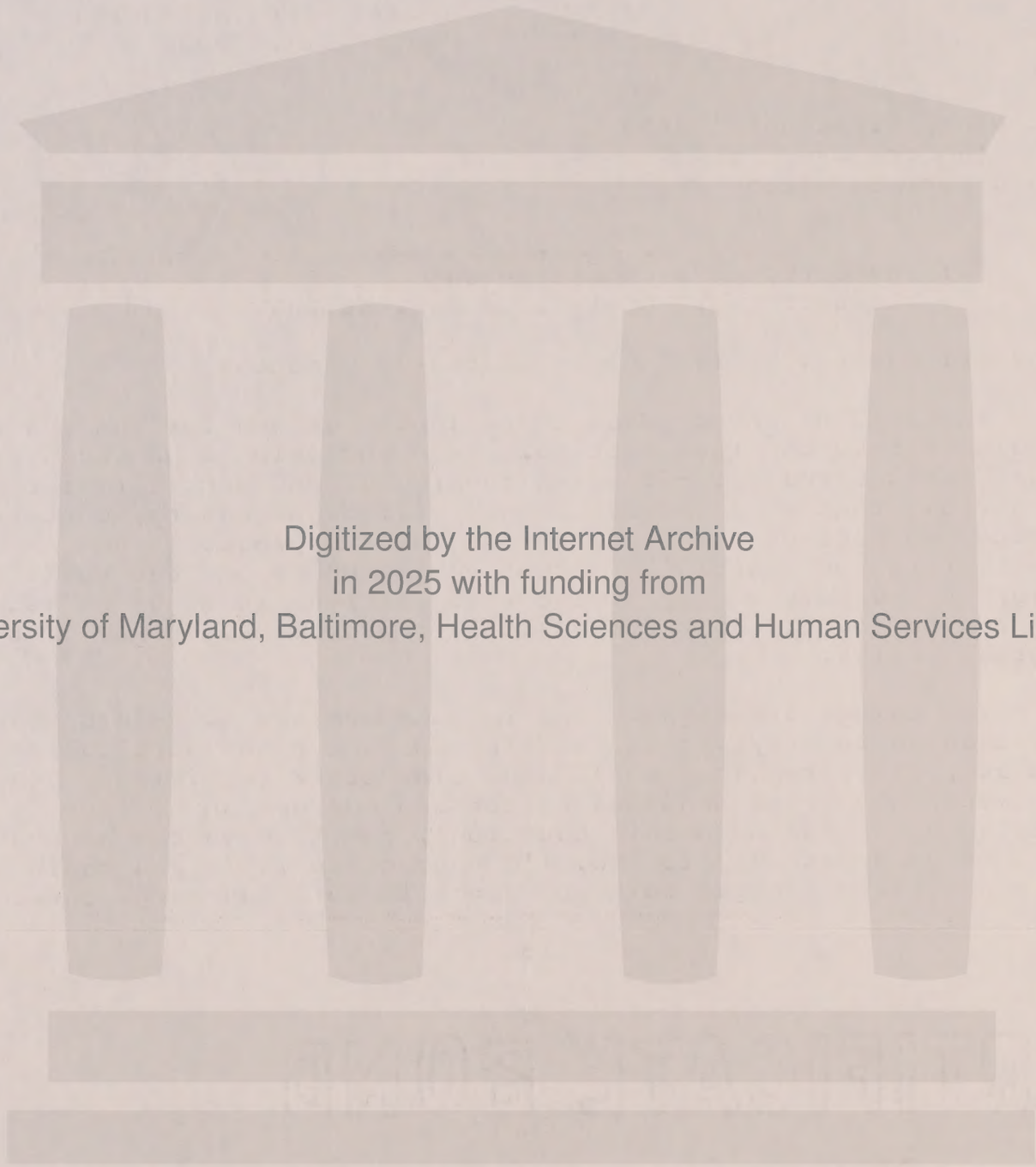
Two things are tight. One is handbook space. Please target any changes to stay within existing space for the particular subject; i.e., replace, don't add. The other is timing. George Woodward, W1RN, the handbook editor and our new Hq Liaison (replacing Ed Kalin in this function), has to have the handbook wrapped up around May 1. So, I'd appreciate it if you could get your suggested changes to me by March 15 so I can merge them.

73,

Paul

Paul L. Rinaldo, W4RI
Chairman

cc : Vic Clark, W4KFC for info only
David Sumner, K1ZZ for info only
George Woodward, W1RN for info only



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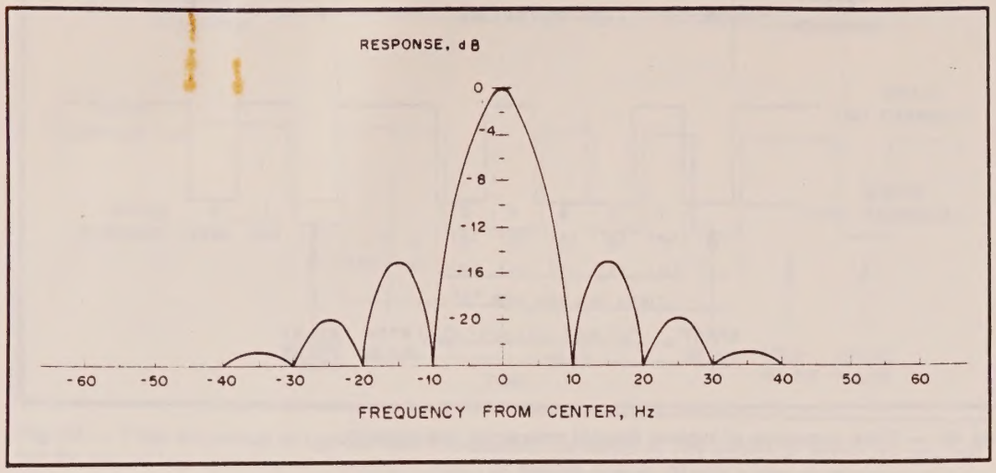


Fig. 59 — Amplitude vs. frequency response of the receiving filter.

too unusual in itself when conditions are good and interference is absent, the channel recorded without the ccw filter was unreadable, while the ccw channel was perfect copy. Woodson publishes a ccw newsletter whenever there is new information to report.

RADIOTELETYPE

Radioteletype (abbreviated RTTY) is a form of telegraphic communication employing typewriterlike machines for (1) generating a coded set of electrical impulses when a typewriter key corresponding to the desired letter or symbol is pressed, and (2) converting a received set of such impulses into the corresponding printed character. The message to be sent is typed out in much the same way that it would be written on a typewriter, but the printing is done at the distant receiving point. The teletypewriter at the sending point may also print the same material.

The teleprinter machines used for RTTY are far too complex mechanically for home construction, and if purchased new would be highly expensive. However, used teletypewriters in good mechanical condition are available at quite reasonable prices. These are machines retired from commercial service but capable of entirely satisfactory operation in amateur work. They may be obtained from several sources on condition that they will be used purely for amateur purposes and will not be resold for commercial use.

Some dealers and amateurs around the country make it known by advertising that they handle parts or may be a source for machines and accessory equipment. *QST*'s Ham Ads and other publications often show good buys in equipment as amateurs move about, obtain newer equipment, or change interests.

Periodic publications are available which are devoted exclusively to amateur RTTY. They carry timely technical articles and operating information, as well as classified ads. Over the years *QST* has carried a number of articles on all aspects of RTTY. For a list of surplus equipment dealers, information on publishers of RTTY periodicals, and a bibliography of all articles on RTTY that have appeared in *QST*, write to ARRL 225 Main St., Newington, CT 06111. U.S. residents should enclose a stamped, business-size envelope bearing a return address with their request.

Types of Machines

There are two general types of machines, the *page printer* and the *tape printer*. The former prints on a paper roll about the same width as a business letterhead. The latter prints on paper tape, usually gummed on the reverse side so it may be cut to letter-size width and pasted on a sheet of paper in a series of lines. The page printer is the more common type in the equipment available to amateurs.

The operating speed of most machines is such that characters are sent at the rate of either 60, 67, 75 or 100 wpm depending on the gearing ratio of a particular machine. Current FCC regulations allow amateurs the use of any of these four speeds. Interchangeable gears permit most machines to operate at these speeds. Ordinary teletypewriters are of the *start-stop* variety, in which the pulse-forming mechanism (motor driven) is at rest until a typewriter key is depressed. At this time it begins operating, forms the proper pulse sequence, and then comes to rest again before the next key is depressed to form the succeeding character. The receiving mechanism operates in similar fashion, being set into operation by the first pulse of the sequence from the transmitter. Thus, although the actual transmission speed cannot exceed about 60 wpm (or whatever maximum speed the machine is geared for), it can be considerably slower, depending on the typing speed of the operator.

It is also possible to transmit by using perforated tape. This has the advantage that the complete message may be typed out in advance of actual transmission, at any convenient speed; when transmitted, however, it is sent at the machine's normal maximum speed. A special tape reader, called a *transmitter-distributor*, and tape perforator are required for this process. A *reperforator* is a device that may be connected to the conventional teletypewriter for punching tape when the machine is operated in the regular way. It may thus be used either for an original message or for "taping" an incoming message for later retransmission.

Start, Data, Stop Pulses

In a teleprinter machine, the normal "rest" condition of the selector-magnet solenoids is with loop current on. Interruption of the loop current releases the selector magnet, allowing rotation of a cam in the machine. Transmission of a TTY character begins with a space pulse (current off), called the *start* pulse. The start pulse signals to the machine that reception of a character has begun. Immediately after the start pulse, a series of *data* pulses is transmitted with mark or space condition as indicated by the encoding for the desired character. The number of data pulses used to represent the letters, numbers and symbols varies with the TTY code being used; Baudot code uses five data pulses, ASCII uses eight. Immediately after the last data pulse, a *stop* pulse is included which is always a mark pulse. The stop pulse, therefore, always occurs in a fixed time after the start pulse (after five data pulses in Baudot and eight in ASCII). The stop pulse gives the machine a "rest time" to prepare for the beginning of the next character, maintaining receive machine synchronization with the transmitted signal. The time length of the start and each data pulse are the same and are often called the unit-pulse or select-pulse time. The stop-pulse length varies from code to code and even with speeds within a code, as will be explained later. In general, the minimum stop-pulse length can be one or two times as long as the unit-pulse time; stop pulses may be as long as desired since the machine is "at rest" until the next start pulse is received. This type of TTY code that uses start, data and stop pulses

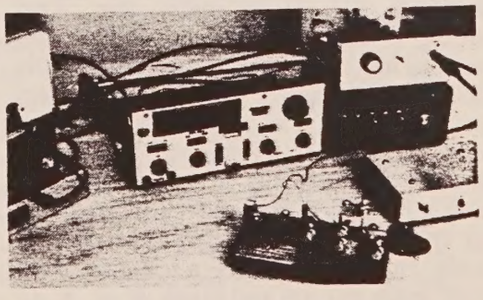


Fig. 60 — This is the first complete amateur station to be built for coherent cw operation. Assembled by Andy McCaskey, WA7ZVC, it consists of a modified Ten-Tec PM-2 transceiver and homemade modules that provide for the control and processing of signals as required for coherent-cw operation.

in the construction of each character is called an asynchronous or start-stop serial code. Other codes also in commercial use include synchronous serial codes, in which start and stop pulses are not attached to the data pulses for each character, and parallel data codes, in which each data pulse is assigned a separate wire to and from the terminal device. Such codes are found in common use with computer and line-printer devices. FCC regulations currently authorize amateurs to use either the Baudot or the ASCII serial asynchronous TTY codes.

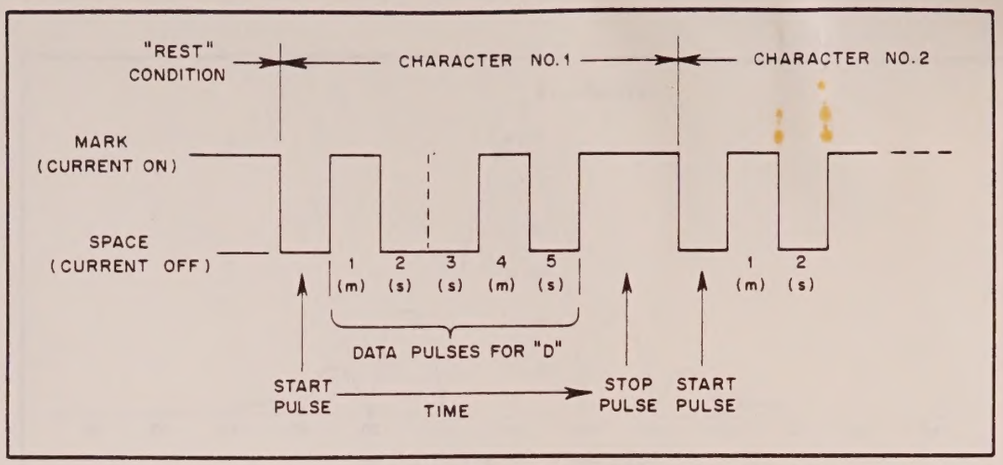


Fig. 61 — Time sequence of typical Baudot character, the letter D.

The Baudot TTY Code

One of the first data codes used with mechanical printing machines uses a total of five data pulses to represent the alphabet, numerals and symbols. This code is commonly called the Baudot or Murray telegraph code, after the work done by these two pioneers. Although commonly called the Baudot code in the United States, a similar code is usually called the Murray code in other parts of the world and is formally defined as the International Telegraphic Alphabet No. 2 Baudot Code in part 97.69 of the FCC Rules and Regulations. This standard defines the codes for letters, numerals and the slant or fraction bar but allows variations in the choice of code combinations for punctuation. U.S. amateurs have generally adopted a version of the so-called "Military Standard" code arrangement for punctuation, largely because of the ready availability of military surplus machines in the post-1945 years. Amateurs in other countries (particularly in Europe) have standardized on the International Consultative Committee for Telephone and Telegraph (CCITT) No. 2 code arrangement, which is similar to the U.S. standard but has minor symbol and code-arrangement differences.

Since each of the five data pulses can be in either a mark or space condition (two possible states per pulse), a total of $2\times2\times2\times2\times2 = 2^5 = 32$ different code combinations are possible. Since it is necessary to provide transmission of all 26 letters, 10 numerals and punctuation, the 32 code combinations are not sufficient. This problem is solved by using the codes twice; once in the *letters* (LTRS) case and again in the *figures* (FIGS) case. Two special characters, LTRS and FIGS, are used to indicate to the printer whether the following characters will be of the letters or figures case. The printer has a latching mechanism that "remembers" or stores the last received LTRS or FIGS character so that it remains in the last received case until changed. Control operations such as LTRS, FIGS, carriage return (CR), line feed (LF), space bar (SP) and blank (BLNK = no print or carriage movement) are assigned to both the LTRS and FIGS case so that they can be sent in either case. The remaining 26 code combinations have different letter or numeral/symbol meanings, depending upon whether preceded by a LTRS or FIGS character.

Keyboards on Baudot machines such as the Teletype Corp. models 15 and 28 differ from standard typewriter keyboards, having only three rows of keys with the related letter and number/symbol on each keytop — Q and 1, K and (, and so on. The typist soon discovers this difference! Newer electronic terminals such as the HAL DS2000 and DS3100 have standard keyboard arrangements and automatically insert LTRS or FIGS characters as they are needed. The Baudot code itself is restricted to upper-case letters only since insufficient codes are available to represent lower-case letters.

The Baudot code has seen extensive commercial use throughout the world and is still actively utilized for international wire, press and weather communications. Because of the ready availability of Baudot mechanical equipment, this code will continue to be quite popular among radio amateurs. Nevertheless, the lack of code space for control, extended punctuation or lower-case letters is a severe limitation of the five-unit Baudot code. These limitations are particularly inconvenient in computer-terminal applications, even though various serial and parallel data-coding schemes have been used with computers. Fig. 61 shows a time diagram of typical Baudot characters, and Table 14 shows the Baudot data code for both the U.S. and CCIT No. 2 alphabet. Notice that the waveform drawing of Fig. 61 shows the *current* waveform, with mark represented by the upper deflection. Additionally, the bits in Fig. 61 are arranged in a left-to-right order, as would be observed on an oscilloscope. The bits in Table 14, however, are arranged in *descending* order (b5 to b1), conforming to the standard binary representation. Thus the letter D shown in Fig. 61 would be written as the binary character 01001.

Table 14
The Baudot Data Code

Bit Number 54321	*Letters*	*U.S. Figures*	*CCITT No. 2 Figures*
00000	BLANK	BLANK	BLANK
00001	E	3	3
00010	LF	LF	LF
00011	A	—	—
00100	SPACE	SPACE	SPACE
00101	S	BELL	'
00110	I	8	8
00111	U	7	7
01000	CR	CR	CR
01001	D	$ ·	WRU
01010	R	4	4
01011	J	'	BELL
01100	N	,	,
01101	F	!	!
01110	C	:	:
01111	K	(	(
10000	T	5	5
10001	Z	"	+
10010	L	)	)
10011	W	2	2
10100	H	#	£
10101	Y	6	6
10110	P	Ø	Ø
10111	Q	1	1
11000	O	9	9
11001	B	?	?
11010	G	&	&
11011	FIGS	FIGS	FIGS
11100	M	.	.
11101	X	/	/
11110	V	;	=
11111	LTRS	LTRS	LTRS

Note: FIGS-H (10100) may also be used for MOTOR STOP function. "1" = mark = hole in punched tape

ASCII

In 1968, the American National Standards Institute (ANSI) adopted the American National Standard Code for Information Interchange (ASCII), ANSI Standard X3.4-1968. This code uses seven data pulses to specify the letter, number, symbol or control operation desired. An eighth data pulse, called the *parity* bit, is provided for optional error checking. As with the Baudot code, the ASCII standard as approved for U.S. amateur use is asynchronous and serial with both start and stop pulses.

Whereas the five-unit Baudot code was arranged by Murray so that the most fre-

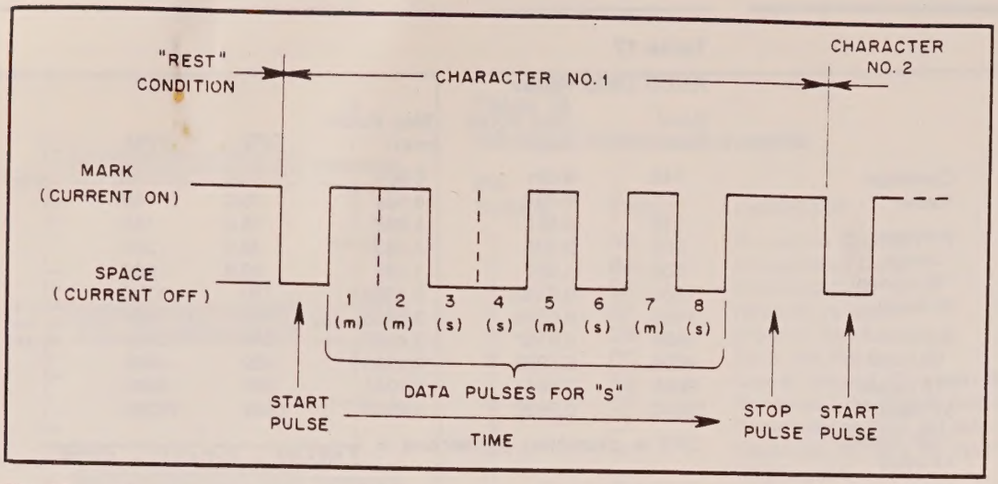


Fig. 62 — Time sequence of typical ASCII character, the letter s. The eighth or parity bit may be set for any of four conditions: (1) always mark, (2) always space, (3) odd parity or (4) even parity. All four choices are in common usage.

Table 15

The ASCII Data Code

7	0	0	0	0	1	1	1	1
6	0	0	1	1	0	0	1	1
5	0	1	0	1	0	1	0	1
4321								
0000	NUL	DLE	SPC	Ø	@	P	\	p
0001	SOH	DC1	!	1	A	Q	a	q
0010	STX	DC2	"	2	B	R	b	r
00011	ETX	DC3	#	3	C	S	c	s
0100	EOT	DC4	$	4	D	T	d	t
0101	ENQ	NAK	%	5	E	U	e	u
0110	ACK	SYN	&	6	F	V	f	v
0111	BEL	ETB	'	7	G	W	g	w
1000	BS	CAN	(	8	H	X	h	x
1001	HT	EM	)	9	I	Y	i	y
1010	LF	SUB	*	:	J	Z	j	z
1011	VT	ESC	+	;	K	[	k	{
1100	FF	FS	,	<	L	\	l	/
1101	CR	GS	–	=	M	]	m	}
1110	SO	RS	.	>	N	^	n	~
1111	SI	US	/	?	O	_	o	DEL

ACK = acknowledge
BEL = signal bell
BS = backspace (←)
CAN = cancel
CR = carriage return
DC1 = device control 1
DC2 = device control 2
DC3 = device control 3
DC4 = device control 4
DEL = (delete)
DLE = data link escape
ENQ = enquiry (WRU)
EM = end of medium
EOT = end of trans.
ESC = escape
ETB = end of block
ETX = end of text

FF = form feed (home)
FS = file separator
GS = group separator
HT = horizontal tab (→)
LF = line feed (↓)
NAK = not acknowledge
NUL = null
RS = record separator
SI = shift in
SO = shift out
SOH = start of heading
SPC = space
STX = start of text
SUB = substitute
SYN = synchronous idle
US = unit separator
VT = vertical tab (↑)

Note: "1" = mark = hole in punched tape

quently used letters are represented by the least number of mark holes punched in paper tape, ASCII has been arranged to optimize computer applications. The code has been particularly designed for rapid collation of alphanumeric lists, one data bit difference between upper- and lower-case letters, and isolation of all control operations from printing operations. A time diagram of a typical ASCII character is shown in Fig. 62. Table 15 shows the ASCII data code. As noted for the Baudot-waveform drawing, Fig. 62 shows the loop current with mark represented by the upward deflection. Furthermore, the bits in Table 15 are arranged in binary number order (b7 to b1). Thus, the letter S in Fig. 62 would be written as the binary number 0101 0011, with the eighth (parity) bit set to space (0), as indicated.

As can be seen from the code table, many more punctuation symbols are included in ASCII than in Baudot. ASCII also includes a large number of control characters designed for print control of the terminal itself, formatting of data to the computer, and control of other hardware devices by the terminal. Although these control functions are defined by the ANSI definition, variations in the use of the control characters abound in the differing commercial applications.

The keyboards of both mechanical and electronic ASCII terminals are arranged similar to the "standard" typewriter keyboard, thus minimizing any retraining required when an operator moves from a typewriter to a terminal. The "extra" ASCII keys are arranged around the periphery of the standard keyset if they are provided at the terminal keyboard.

A common abbreviation of the full 128-character ASCII code restricts the alphabetic letters to upper-case only, often called CAPS-LOCK or ϵAPLK. In general, these terminals transmit the upper-case ASCII code for a letter whether the SHIFT key is used or not; they may or may not be capable of transmitting all of the control codes. These terminals usually print (or display) the upper-case letter when either the upper- or lower-case letter ASCII code is received. The Teletype model 33 is an example of a popular upper-case-only ASCII terminal. Other terminals, such as the Teletype model 43 or the HAL DS3100 ASR, have user-selectable upper/lower case or upper-case-only (CAPSLK) transmit/receive features.

The optional eighth data bit may be set to four conditions: (1) always mark, (2) always space, (3) odd parity, or (4) even parity. All four choices are in common usage. Simple non error-detecting terminals usually set the eighth bit to be always a mark or space (usually space). Parity is sometimes used with computer and data interconnections where error-detection is desired. When used, the parity bit is controlled so as to set the total number of mark data bits in the ASCII character to be always even or odd (even or odd parity). For example, if odd parity is used with the ASCII character C (first seven bits = 100 0011), the eighth parity bit will be set to space to give an odd number (3) of data bits (0100 0011). Conversely, the odd-parity eight-bit code for the letter B would be 1100 0010. (Logic convention has it that lowest order bits are placed to the right; thus the bit order in the binary representation is 8765 4321.) Upon reception, the receiving terminal simply counts the number of mark pulses in each ASCII 8-bit character. If an odd number is counted, it is *assumed* that no errors occurred. Notice, however, that even if a bit error is detected, there is insufficient data to determine which bit was wrong, and therefore no error *correction* is provided by the parity check itself. If there are two bit errors in the same ASCII character, the parity count will still be odd, and no error indication is

Table 16
Baudot Data Rates and Speeds

Baud Rate	Data Pulse (ms)	Stop Pulse (ms)	WPM	Common Name
45.45	22.0	22.0	65.00	Western Union
	22.0	31.0	61.33	"60 speed"
	22.0	33.0	60.61	45 baud
50.00	20.0	30.0	66.67	European; 50 baud
56.92	17.57	25.00	76.68	"75 speed"
	17.57	26.36	75.89	57 baud
74.20	13.47	19.18	100.00	"100 speed"
	13.47	20.21	98.98	74 baud
100.0	10.00	15.00	133.33	100 baud

Table 17
ASCII Data Rates

Baud Rate	Data Pulse (ms)	Stop Pulse (ms)	CPS	WPM
110	9.091	9.091	11.0	110
	9.091	18.182	10.0	100
150	6.667	6.667	15.0	150
300	3.333	3.333	30.0	300
600	1.667	1.667	60.0	600
1200	0.8333	0.8333	120	1200
1800	0.5556	0.5556	180	1800
2400	0.4167	0.4167	240	2400
4800	0.2083	0.2083	480	4800
9600	0.1041	0.1041	960	9600
19200	0.0520	0.0520	1920	19200

$$\text{CPS} = \text{characters per second} = \frac{1}{\text{START} + 8\,(\text{DATA}) + \text{STOP}}$$

$$\text{WPM} = \text{words per minute} = \frac{\text{CPS}}{6} \times 60$$

= number of 5-letter-plus-space groups per minute.

given even though two errors occurred. Thus, parity checking will not give complete error detection and does not provide for error correction. Some applications require more sophisticated error detection and correction schemes. Even parity works in a similar manner, except that the eighth bit is chosen to make the total number of mark pulses even rather than odd. The U.S. amateur regulations do not specify a requirement for use of the eighth data bit; it may be set to mark, space, odd or even parity, depending upon the preference of the operator and the capability of his equipment. Relatively simple terminals do not provide parity options; more sophisticated equipment such as the DS3100 ASR does.

Speeds and Baud Rates

The transmission rate of Baudot TTY signals is usually specified in words per minute, much like that used for telegraph codes. Actually, the speed is given in the *approximate* number of five-letter-plus-space combinations transmitted in a *continuous sequence* of start-stop characters in a one-minute interval. Convenient choices of gear ratios and motor-shaft speeds have resulted in the use of noninteger wpm rates. Common usage, however, has rounded the exact speeds to easily remembered numbers. Thus, "60 speed" Baudot is actually sent at 61.33 wpm and "75 speed" is really 76.67 wpm.

A major problem occurs with the use of words per minute as a TTY speed specification because of the varying length of stop pulses in use. For example, "60 speed" Baudot TTY has 22-ms-long start and data pulses and a 31-ms stop pulse; the Western Union "65 speed" also has 22-ms start and data pulses, but the stop pulse is also 22-ms long; electronic terminals commonly use 22-ms start and data pulses and 33-ms stop pulses (1.5 times the data-pulse width). All of these three codes are compatible and may be received on the same printer or terminal since the stop-pulse length is a *minimum* time. The common factor between these codes is the 22-ms length of the data, or unit pulse. Therefore, a new data-rate specification has been adopted, the *baud* rate, which is the reciprocal of the data- or unit- or select-pulse width:

Baud rate = 1/t, where t = length of unit pulse.

Using this definition, all three of the above codes have a data rate of 45.45 baud, commonly abbreviated to "45 baud."

As noted above, the length of the stop pulse varies between codes, being from 1.0 to 2.0 times as long as the unit (or data) pulse; multipliers of 1.0, 1.42, and 1.5 are commonly used with the Baudot codes. Standard Baudot data rates and speeds are shown in Table 16.

U.S. amateurs are authorized to use all of the Baudot data rates shown in Table 16 with the exception of 100 baud. This rate has seen limited commercial use in Europe. The 45-baud data rate is by far the most popular worldwide amateur data rate. A limited amount of amateur use of 74 baud ("100 speed") has been noted on the high-frequency bands. Most commercial RTTY transmissions on high frequencies use 50, 57 and 74 baud, with little 45-baud activity.

ASCII data rates are commonly specified as a baud rate, although a character-per-second (cps) or words-per-minute (wpm) rate may also be given. The lowest standard ASCII data rate in common usage is 110 baud. ASCII characters sent at 110 baud are usually sent with a 2-unit-wide stop pulse, although the 1-unit stop pulse may also be found in some applications. Above 110 baud, it is common to make the stop pulse one unit pulse in length. The standard ASCII data rates commonly used with asynchronous serial transmission are shown in Table 17.

The ASCII data rates up to 300 baud are authorized for U.S. amateur use on frequencies between 3.500 and 21.250 MHz. Data rates up to 1200 baud are permitted between 28 and 225 MHz; up to 19,600 baud may be used above 420 MHz. The 110-baud rate is by far the most practical for 3.5 to 21.5 MHz use, again because of the ready availability of equipment as well as the increased susceptibility of the higher data rates to noise, static, interference and so forth. Vhf fm amateur activity finds 110 and 300 baud useful for terminal-to-terminal communications, and 300 and 1200 baud for computer-related activities such as exchanging programs and the like.

Loop Circuits

As discussed earlier, the printing mechanisms use solenoids or selector magnets to sense the presence (mark) or absence (space) of the loop current. The letters typed on the sending keyboard are encoded with proper mark and space pulses by mechanically driven keyboard contacts. Since the keyboards and selector magnets of both machines are series connected, text typed on one keyboard is reproduced on both printers. Connection of the keyboard directly to its associated printer is called a local loop and results in what is called half duplex (HDX), giving local copy of transmitted text, termed local echo.

Selector magnets have been designed for mark loop currents of 60 or 20 mA dc, with 60 mA being by far the most common for older machines such as the Teletype Corp. model 15 or 28. Newer Baudot machines and most ASCII machines and terminals use electronic interface circuits that accept a wide range of loop currents (10 to 120 mA for the HAL DS3100, for example); a 20-mA loop current is quite commonly used with ASCII terminals.

Since the dc resistance of the machine

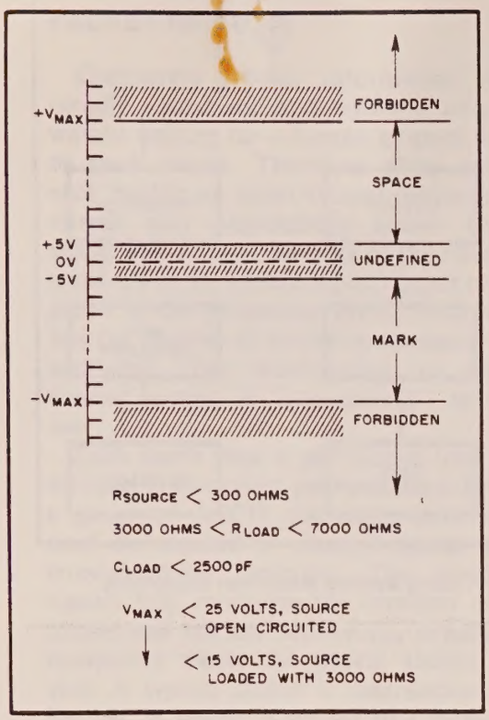


Fig. 63 — RS-232-C voltage standards. Note that these voltages are *not* compatible with TTL integrated circuits.

Table 18
RS-232-C Interface Connector

Pin Number	*Circuit*	*Description*	*Abbreviation*
1	AA	Protective Ground	PG
2	BA	Transmitted Data	TXD
3	BB	Received Data	RXD
4	CA	Request to Send	RTS
5	CB	Clear to Send	CTS
6	CC	Data Set Ready	DSR
7	AB	Signal Ground (Common Return)	SG
8	CF	Received Line Signal Detector	CD
9	—	Reserved for data set testing	
10	—	Reserved for data set testing	
11	—	Unassigned	
12	SCF	Secondary Received Line Sig. Detc.	
13	SCB	Secondary Clear to Send	
14	SBA	Secondary Transmit Data	
15	DB	Transmit Signal Clock	TXC
16	SBB	Secondary Received Data	
17	DD	Receive Signal Clock	RXC
18	—	Unassigned	
19	SCA	Secondary Request to Send	
20	CD	Data Terminal Ready	DTR
21	CG	Signal Quality Indicator	
22	CE	Ring Indicator	RI
23	CH/CI	Data Rate Selector (DTE/DCE Source)	
24	DA	Transmit Signal Clock to Modem	
25	—	Unassigned	

Use of a 25-pin connector is assumed but not defined in the RS-232-C standard. Commercial usage has seen the adoption of the TRW-Cinch D-Subminiature connector series (DB25P and DB25S), also manufactured by many other firms (Amphenol 17-10250 and 17-20250, for example). In general, the male pin connector (DB25P or 17-20250) is installed on the data terminal, but other arrangements may be found on some equipment.

selector magnets is rather low (100 to 300 ohms, typically), it would at first seem that a low-voltage loop supply could be used. However, the inductance of the magnet is usually quite high (on the order of 4 henrys for a model 15), causing a delay in the current rise time. This, in turn, delays the selector magnet response to a mark pulse, distorting the signal. This distortion can be severe enough to cause misprinting of received text, particularly if other forms of distortion are present (such as caused by variations in the radio signal). The effect of this inductive distortion is reduced considerably if the L/R ratio (L is solenoid inductance and R is total loop resistance) is reduced by increasing R. Increasing R requires that the dc voltage be increased to maintain the required 60-mA loop current. In general, the higher the loop voltage and loop resistance used, the lower the distortion. In practice, loop power-supply voltages between 100 and 300 Vdc are common; 130- and 260-volt supplies were often used with model 15, 19 and 28 Teletype machines. Modern TTY systems use a 150- to 200-volt loop power supply and a 2000- to 3000-ohm loop resistance to set the 60-mA loop current. Because of the related keying circuitry, the demodulator unit of a good RTTY system usually includes the loop power supply and current-limiting resistor.

On the other hand, the newer ASCII machines (such as the Teletype Corp. models 33, 35 and 43) are available with a wide variety of input/output (I/O) interfaces. These devices usually include a high-current, low-voltage selector-magnet assembly (500 mA, 10 to 30 volts is typical), an internal magnet-driver transistor and power supply, and an electronic interface to the data connections. These machines may be supplied with a 20-mA loop-interface circuit or other interface standards.

RS-232 Data Interface

The EIA has defined a standard for interconnection of terminals, modems and computers in *EIA Standard RS-232-C* (August 1969). This interface standard specifies *voltage* levels for mark and space, rather than the current levels used in a loop circuit. The basic RS-232-C voltage ranges are shown in Fig. 63.

Note that mark, normally considered to be a logic 1, is represented by a negative voltage and the logic 0 by a positive voltage. Thus, the RS-232 interface standard can be thought of as a polar voltage standard. Also, note that RS-232 voltage levels really are *not* transistor-transistor logic (TTL) compatible (in spite of some claims you may read to the contrary)! Users should carefully examine "pseudo RS-232-compatible" equipment to make sure no damage will be caused to their RS-232-interfaced equipment. The RS-232-C standard also includes definition of control signals to pass between originating and receiving devices, and even defines the connector-pin assignment. The RS-232 connector signal and pin assignments are shown in Table 18.

The control signals such as DATA TERMINAL READY (DTR), REQUEST TO SEND (RTS), and so forth, are often called *handshaking* signals; they provide status indicators between data devices (terminal to and from a modulator/demodulator or modem, for example). All control-signal voltage and impedance levels also conform to the RS-232-C standard shown in Fig. 63. Control signals are considered to be active or on when the voltage is positive; a negative-voltage control signal is off or inactive. The terms "mark" and "space" are usually not used when describing RS-232 control signals. Thus a positive voltage on pin 5 (CB = CLEAR TO SEND) is the terminal's signal to the data circuit that the terminal is ready to receive data. Further, an open-circuit or no-voltage condition on an RS-232 signal is interpreted as a "mark" or "active" condition.

Other Data-Connection Standards

A number of other data-connection standards may be found in use in commercial equipment. Chief among these is an interface that is compatible with the popular TTL integrated circuits, a TTL-compatible interface. TTL interconnections are particularly useful when directly interfacing computers or other digital devices. Although TTL and RS-232 interface standards are not directly compatible, a number of line-receiver and line-driver integrated circuits are available.

A common data standard used in U.S. military applications is the MIL-188 Data Standard. MIL-188 is very similar to the RS-232 standard, with the exception that logic voltages are inverted — mark is represented by positive voltages and space

by negative voltages.

Other data interfaces are to be found for CMOS logic integrated-circuit connections. Interfaces for both +5-volt and +12-volt CMOS operation are in use.

Additional System Requirements

To be used in radio communication, the pulses (dc) generated by the teletypewriter must be utilized in some way to key a radio transmitter so they may be sent in proper sequence and usable form to a distant point. At the receiving end the incoming signal must be converted into dc pulses suitable for operating the printer. These functions, shown in block form in Fig. 64, are performed by electronic units known respectively as the *frequency-shift keyer* or RTTY modulator and *receiving converter* or RTTY *demodulator*.

The radio transmitter and receiver are quite conventional in design. Practically all the special features needed can be incorporated in the keyer and converter, so that most ordinary amateur equipment is suitable for RTTY with little or no modification.

Transmission Methods

It is quite possible to transmit teleprinter signals by ordinary "on-off" or "make-break" keying such as is used in regular hand-keyed cw transmissions. In practice, however, *frequency-shift keying* is preferred because it gives definite pulses on both mark and space, which is an advantage in printer operation. And, since fsk can be received by methods similar to those used for fm reception, there is considerable discrimination against noise, both natural and manmade, distributed uniformly across the receiver's passband, when the received signal is not too weak. Both factors make for increased reliability in printer operation.

Frequency-Shift Keying

On the vhf bands where A2 and F2 transmission is permitted, *audio frequency-shift keying* (afsk) is generally used. In this case the rf carrier is transmitted continuously, the pulses being transmitted by frequency-shifted tone modulation. The audio frequencies used have been more-or-less standardized at 2125 and 2295 Hz, the shift being 170 Hz. With afsk, the lower audio frequency is customarily used for mark and the higher for space.

Below 50 MHz, F1 or fsk emission is used. The carrier is on continuously but its frequency is shifted to represent marks and spaces. General practice with fsk is to use a frequency shift of 170 Hz, although FCC regulations permit the use of any value of frequency shift up to 900 Hz. The smaller values of shift have been shown to have a signal-to-noise-ratio advantage. The nominal transmitter frequency is the mark condition and the frequency is shifted 170 Hz (or whatever shift may have been chosen) lower for the space signal.

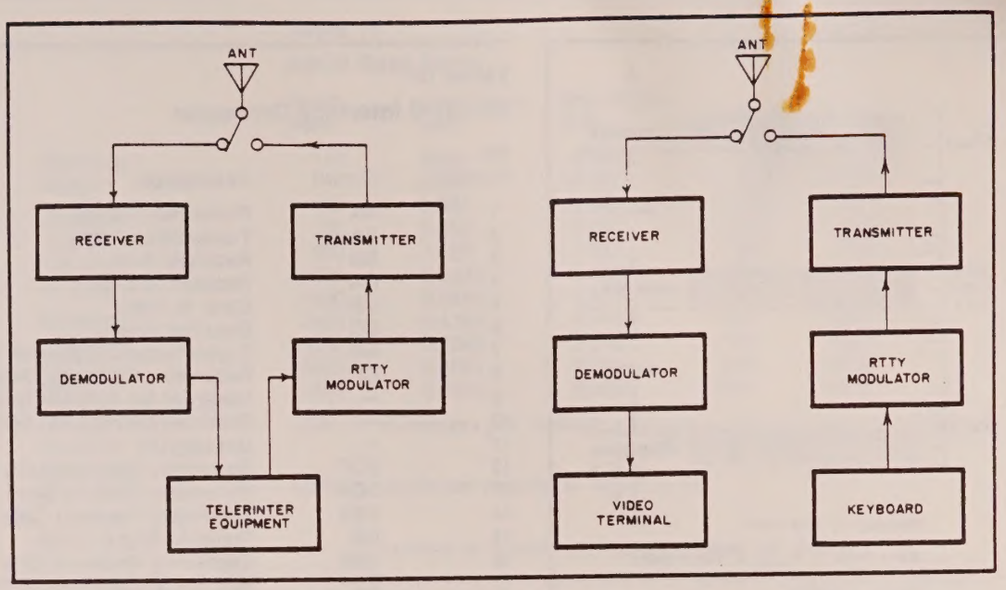


Fig. 64 — At left is a block diagram of an RTTY system using surplus teleprinter equipment. At right, a modern all-electronic RTTY station setup.

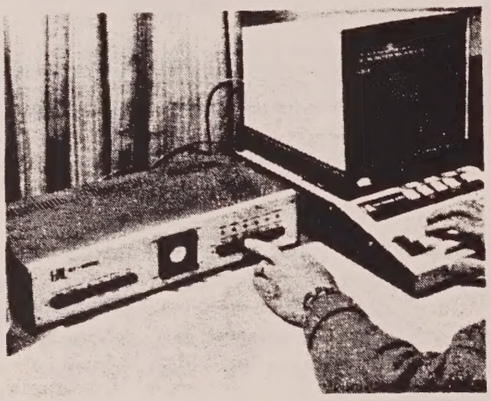


Fig. 65 — Many RTTY operators now use all-electronic systems.

RTTY with SSB Transmitters

Amateurs operating RTTY in the hf bands are using audio tones fed into the microphone input of an ssb transmitter. With properly designed and constructed equipment which is correctly adjusted, this provides a satisfactory method of obtaining F1 emission. The user should make certain, however, that audio distortion, carrier, and unwanted sidebands are not present to the degree of causing interference in receiving equipment of good engineering design. *The user should also make certain that the equipment is capable of withstanding the higher-than-normal average power involved.* The RTTY signal is transmitted with a 100-percent duty cycle, i.e., the average-to-peak power ratio is 1, while ordinary speech waveforms generally have duty cycles in the order of 25 percent or less. Many ssb transmitters such as those using sweep-tube final amplifiers, are designed only for low-duty-cycle use. Power-supply components, such as the plate-voltage transformer, may also be rated for light-duty use only. As a general rule when using ssb equipment for RTTY operation, the dc input power to the final PA stage should be no more than twice the plate dissipation rating of the PA tube or tubes.

Bibliography

A bibliography of RTTY articles from *QST* is available from ARRL Hq. for a large s.a.s.e.

American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018

ANSI X3.4-1977 American National Standard Code for Information Interchange

ANSI X3.15-1976 American National Standard for Bit Sequencing of the American National Standard Code for Information Interchange in Serial-By-Bit Data Transmissions

ANSI X3.16-1976 American National Standard Character Structure and Character Parity Sense for Serial-By-Data Communication in the American National Standard Code for Information Interchange

ANSI X3.28-1976 American National Standard Procedures for the Use of Control Characters of American National Standard Code for Information Interchange in Specified Data Communications Links

Electronic Industries Association, EIA Engineering Department, Standards Orders, 2001 Eye St., N.W., Washington, DC 20006

EIA Standard RS-232-C Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange

EIA Standard RS-269-B Synchronous Signaling Rates for Data Transmission

EIA Standard RS-363 Standard for Specifying Signal Quality for Transmitting and Receiving Data Processing Terminal Equipments Using Serial Data Transmission at the Interface with Non-Synchronous Data Communication Equipment

EIA Standard RS-404 Standard for Start-Stop Signal Quality Between Data Terminal Equipment and Non-Synchronous Data Communication Equipment

EIA Industrial Electronics Bulletin No. 9: Application Notes for EIA Standard RS-232-C

Goacher and Denny, *The Teleprinter Handbook*, Chapters 1, 2 and 3. Radio Society of Great Britain, 35 Doughty St., London WC1N 2AE, 1973.

Guentzler, "RTTY for the Beginner," pp. 3-24, *RTTY Journal*, P. O. Box RY, Cardiff by the Sea, California 92007, 1975

Kretzman, *The New RTTY Handbook*, Chapters 1 and 2, Cowan Publishing Corp., 14 Vanderventer Ave., Port Washington, NY, 1962

Schwartz, "An RTTY Primer," *CQ Magazine*, issues of August 1977, November 1977, February 1978, May 1978, July 1978 and August 1978

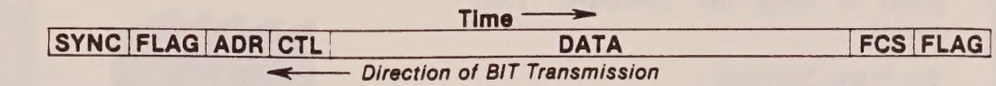
Tucker, *RTTY from A to Z*, Chapters 1, 2, 3 and 11, Cowan Publishing Corp., 14 Vanderventer Ave., Port Washington, NY, 1970

Reference Data for Radio Engineers, Fifth Edition, Chapter 30, Howard W. Sams & Co., Inc., a subsidiary of International Telephone and Telegraph Corporation, Indianapolis, Kansas City and New York, 1968.

Computers process information very rapidly. Most of a computer's time is wasted waiting for a human to enter data or read output. Therefore many users, each having an input/output device (terminal) may sequentially access (time share) a computer. Because of the relative slowness of the human input/output compared to the processing speed, each user has the illusion of exclusive access to the computer. The multiplexing, or time-sharing system is "transparent" to the user.

Each user's data is partitioned into individual bursts called *packets*. A packet is a group of ASCII characters (information) surrounded by control signals and error-detection features. The control signals help recognize the presence of a packet and tell any intervening switching equipment where the packet should be sent. A typical packet is diagrammed in Fig. 66. A packet is similar to a message format. Besides carrying smaller payload, the header and trailer components are designed to be read by computer, not by human operators. The computer, in this case, can be either a home computer programmed to perform this function or a packet controller — a single-purpose microcomputer board dedicated to this task. There are advantages to the packet-controlled board approach, such as (a) taking advantage of packet controller chips on the market, (b) keeping the hardware costs low by not tying up the personal computer and (c) avoiding the necessity of generating new software for every type of computer as changes are made.

Following this philosophy, a typical vhf Amateur Radio packet station would look like that in Fig. 67. The terminal in this case could be either a cathode-ray tube (CRT) or printer and could operate in either ASCII or Baudot code. The Terminal Node Controller (TNC) of the type designed by Doug Lockhart, VE7APU, can be programmed by means of programmable read-only memories (PROMs) to handle serial or parallel communication with a wide variety of terminals, including computers. The other side of the TNC manages the line — sending and receiving packets in High-Level Data Link Control (HDLC) format.



SYNC — First packet in a group of packets contains 16 bits of alternating zeros and ones.
FLAG — 8 bits, always 01111110 (7E hex).
ADR — Address of the sending station, either assigned dynamically by the Station Node at sign-on or hard-coded into the Terminal Interface Program (8 bits).
CTL — 8 bits containing control information for handling the packet.
DATA — From 0 (supervisory packet) to 255 bytes of data in ASCII.
FCS — Frame Check Sequence — 16 bits, computed by the sending station and checked by the receiving station.
FLAG — 8 bits, always 01111110 (7E hex).

Fig. 66 — Format for a typical packet.

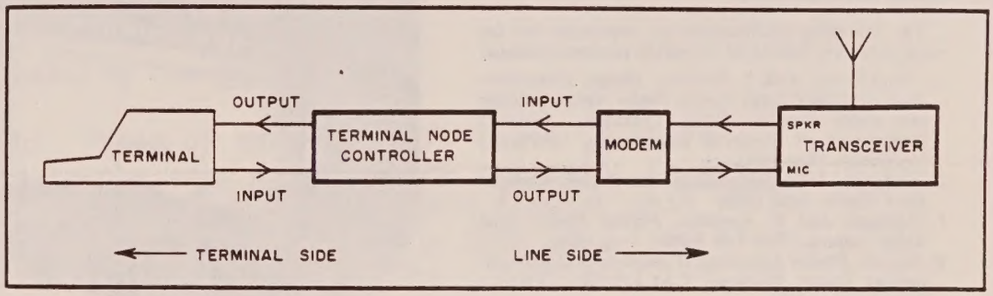


Fig. 67 — Block diagram showing a typical vhf packet radio station. The arrows indicate the direction of data flow.

Example Packet Transmissions

Assume that the source station wishes to send a two-page message to a destination station using packets. The transmission might be broken up into 48 packets, each containing the address of the source and destination, an information (data) field containing a part of the total message and a frame check sequence (FCS) for error detection. The source station would enter his message into a computer terminal attached to a Terminal Node Controller. The TNC would accept the message as input, break it up into packets, send the packets over the transmission medium (radio, in this case) and receive an acknowledgment of correct reception from the destination station for each packet sent. The destination station would also employ a TNC to receive the packets, acknowledge correctly received packets (ASCII ACK) or request retransmission of any bad packets (ASCII NAK or negative acknowledgment). Bad packets are detected using the FCS. An FCS is appended to each packet by the transmitting station. The receiving station computes what the FCS should be and compares that with the FCS supplied with the packet. If the two agree, the chances are very great that the packet is error free. If the two answers disagree, the destination station knows that the packet is bad and requests retransmission of that packet only.

If two stations happen to send packets simultaneously, the result is a "collision." There are numerous so-called contention schemes to avoid collisions, but they happen even in the best packet networks. In this case, the TNC performs a carrier-sense check (to see if anyone is using the channel). To reduce the possibility of two TNC boards hearing nothing and bursting packets at exactly the same time, a variable time delay is built in. Because the time delay at each TNC (user) is changing, repeated collisions between the same pair of users should not occur.

Local Repeaters

In packet terminology, Local Area Network (LAN) is used to designate a number of terminals within a small geographical area that are able to talk to one another through a common channel. That may be coaxial cable or radio. This type of repeater may be quite different from the usual ham 2-meter fm variety. Because local area network packet repeaters are still highly experimental, those now operating or in the construction stage in the U.S. and Canada represent different approaches. As examples of two implementations of local area networks using the same Vancouver TNC boards and HDLC protocol, let us look briefly at San Francisco and Washington, DC.

The KA6M/R local area network packet repeater was activited on December 10, 1980. It is a single-frequency repeater that accepts packets, performs an error check on them and retransmits them when the packets contain no errors. The repeater itself uses a Z-80 microprocessor driving a custom-built board containing a Western Digital 1933 HDLC chip. Bell 202 1200-baud modems are used both at the repeater and by members of the net. Individual stations are using Vancouver TNC boards.

The WD4IWG/R repeater is a 2-meter fm voice repeater that is also used by local AMRAD members for data communications. So, what comes in is repeated on the output frequency at the same time. This approach has the advantages of (1) using an existing repeater and (2) being able to sense the repeater output for presence of carrier before transmitting, avoiding collisions when the other station cannot be heard directly. Like those local networks

in Vancouver, San Francisco and Hamilton, Ontario, the Washington, DC group is using the Vancouver TNC boards.

The Wider Network

The eventual goal is to tie these and many other local areas together to form a larger packet network. The focus, at the moment, is on interconnecting the various groups in Canada and the U.S. Computer enthusiasts are using the acronym AMNET to designate this wider network, which may go much beyond North America.

More Information

The following publications are recommended for radio amateurs interested in packet communications:

R. Forchheimer and I. Persson, *Design Considerations of a Distributed Packet Radio Network Using the Radio Amateur Band*. Linköping, Sweden: Department of Electrical Engineering, Linköping University, May 1980.

I. Hodgson, "An Introduction to Packet Radio," *Ham Radio*, June 1979.

I. Hodgson and R. Rouleau, *Packet Radio*. Blue Ridge Summit, PA: Tab Books, Inc., 1981.

R. Rosner, *Packet Switching: Tomorrow's Communications Today*. Belmont, CA: Lifetime Learning Publications, 1981.

M. Schwartz, *Computer-Communication Network Design and Analysis*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1977.

W. Skees, *Computer Software for Data Communications*. Belmont, CA: Lifetime Learning Publications, 1981.

Additionally, these organizations regularly publish newsletters with substantial packet information:

Amateur Radio Research and Development Corp. (AMRAD), monthly *AMRAD Newsletter* ($12). Gerald Adkins, N4GA, 1206 Livingston St. North, Arlington, VA 22205.

Vancouver Amateur Digital Communications Group (V.A.D.G.C.), *The Packet* ($10). Don Oliver, VE7AOG, 818 Rondeau St., Coquitlam, BC V3J 5Z3 Canada.

Hamilton Area Packet Network (H.A.P.N.), *I-Frame de VE3PKT* ($10). Stu Beal, VE3MWM, 2391 Arnold Cres., Burlington, ON L7P 4J2 Canada.

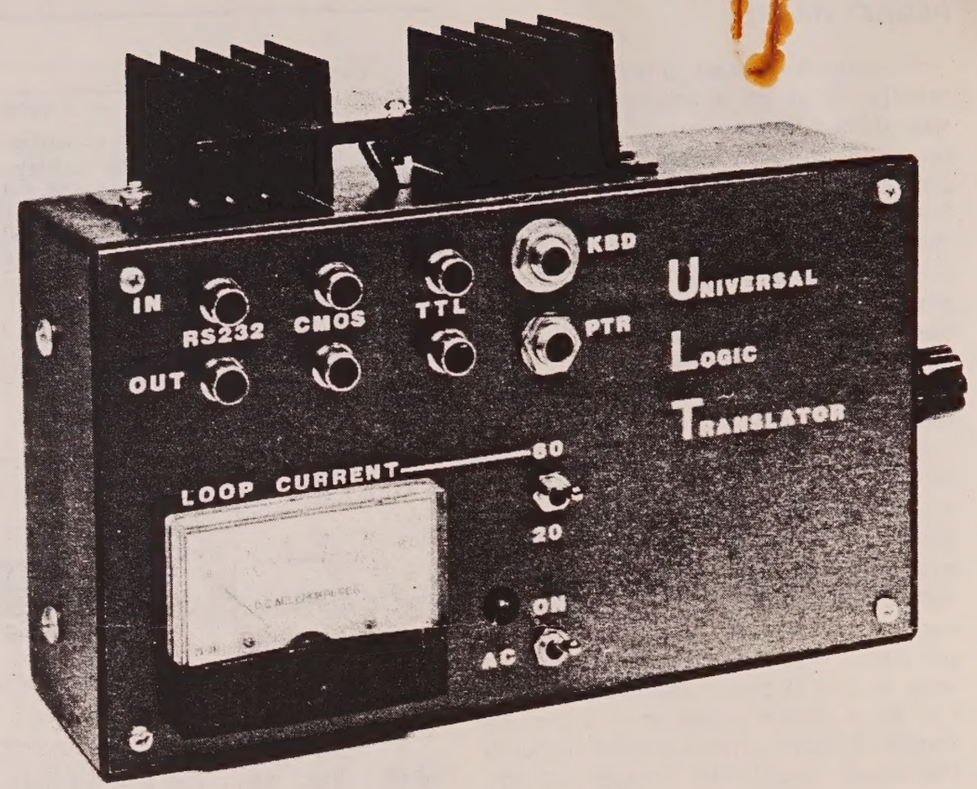


Fig. 68 — A universal logic translator for data communications, built in the ARRL laboratory by Gerry Hull, VE1CER. Fsk outputs or a loop standby switch were not included in this model.

A UNIVERSAL LOGIC TRANSLATOR FOR DATA COMMUNICATIONS

The RTTY or computer enthusiast may encounter frustration when trying to assemble a radio station for digital communications — once all the equipment has been gathered together the amateur is faced with the problem of interconnecting units having widely varying input and output characteristics. "Interfacing" is the buzzword used in the computer industry to describe the mating procedure. The device pictured in Fig. 68 is designed to solve the interfacing problem by acting as a go-between for practically any combination of digital devices likely to be found in an Amateur Radio station.

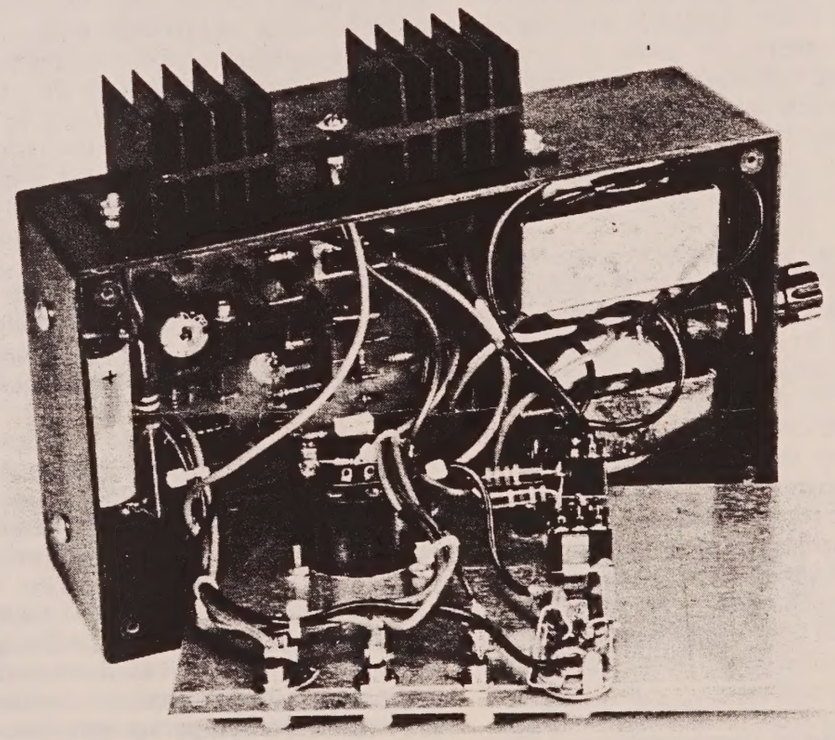


Fig. 69 — Assembly view of the universal logic translator with the front panel folded down to expose the pc board and power supply components. The unit is built into a plastic housing measuring 7-3/4 × 4-3/8 × 2-3/8 inches. The heat sink outside the case is for Q4.

The Electronics

As shown in Fig. 70, the main ingredient of the logic translator is U1, an array of op amps used as comparators. Each comparator input is wired so that the output ports will be in the MARK condition in the absence of input; no external terminations are required for unused ports. An active HIGH at the CMOS input will cause all outputs to go to the SPACE condition. An active LOW is required to achieve this result from the TTL input. J3 presents the proper load to any true RS-232 device, but only the positive logic excursion is active. This input has the same polarity as the CMOS input. J4 accommodates dry contacts from a teleprinter keyboard. Open-

10701 Five Forks Road
Frederick MD 21701
301-293-2448 home
703-442-2083 work
1983 January 16

Dear Paul:

Information for updating the Handbook:

1. p. 14-42, middle column: Types of Machines. It might be appropriate to drop references to the tape printer here and refer to the "glass TTY" CRT. The CRT (or, more correctly, video display unit VDU) is certainly gaining in popularity. It has been a long long time since gummed-tape teletypewriters have been very popular. Similarly, in the right column at the top, some words about transmission from electronic memories as well as paper tape would be appropriate.

2. The bottom of p. 14-42 and top of 14-43 confuses two concepts: code and method of transmission. The distinction between transmission method (serial start-stop, serial synchronous, and parallel) and code (e.g., Baudot and ASCII) should be clarified. The current text suggests that a different code (i.e., NOT Baudot and ASCII) is used for transmission methods which are not serial start-stop.

3. P. 14-43, left column. International Telegraphic Alphabet #2 (ITA #2) referred to in the middle paragraph, and CCITT No. 2 referred to at the end of the same paragraph, are the same. CCITT is the body which standardized ITA #2. But ITA #2 allows for national definition of some of the figures case character positions. That is the reason for the variation illustrated in Table 14. Also, in this same paragraph, the name of the CCITT should be corrected to read "International Telegraph and Telephone Consultative Committee",the correct English name for this group. The acronym CCITT comes from the French name. The word "telegraph" comes before "telephone" because telegraphic services were available before telephone services were. The last sentence of this paragraph should be corrected to reflect all of the above points. Also drop the reference to the "U.S. standard" because there is no formal industry standard in the USA on filling in the national options in ITA#2 figures case. As you may know, different solutions have been used in the USA. The one employed by Western Union was radically different from the one employed by the Bell System, which was slightly different from that used by the DoD. Furthermore, the International Civil Aviation Organization (ICAO) and the World Meteorological Organization (WMO) employ a different figures case from ITU for conveying meteorological information internationally. Machines with the ICAO/WMO character set are often available to amateurs, but this character set does not comply with ITA#2 because of deviation from the agreed figures case characters which are NOT national options in ITA#2. This information that I just gave you is not Handbook material; but it gives you a further background on the scope of this area.

4. p. 14-43, middle column, near the bottom: A typo "CCIT" should be "CCITT", or better yet, "ITA #2". Also at this point, reference to

"descending" order is made. This is rather confusing (descending from what? the answer is descending powers of 2, but this concept is not explained here...). I would simplify this by stating that the bits in Table 14 are arranged conforming to standard binary representation, Transmission is done from right to left in this case. (A fistful of American National Standards and International Standards and CCITT standards apply to this point. If you really want the references I will give them to you.)

5. Table 14 does not explain "WRU". "WRU" is an abbreviation for "who are you?", a function employed in Telex networks. Since "WRU" is not defined anywheres in the text, you might wish to include a fine-print note in the table.

6. ASCII. The first adoption of ASCII by ANSI was done before 1968 (I'll have to research to find the correct date.) Furthermore, the reference to X3.4-1968 should be updated, as I believe this standard has been reaffirmed by ANSI since that time and would thus be designated X3.4-1977 or some such year. This can be clarified by calling the Computer and Business Equipment Manufacturers' Association (CBEMA), 311 First Street NW, Washington DC (202-737-8888), and asking for the X3 Secretariat. Ask them for the current reference year for X3.4.

CCITT has standardized an internationally equivalent code to ASCII. This is called International Alphabet 5 (IA5). It is also an International Standard (published by the International Standards Organization, ISO). Since the Handbook has an international audience, mention of IA5 would be just as appropriate as the mention of ITA#2 was earlier. And, as in the case of ITA#2, there are a number of nationally-defined character positions in IA5; e.g., currency symbol.

7. The caption for Fig. 62 indicates the lower case "s" is illustrated. In fact, upper case "s" is illustrated.

8. Table 15, the row containing IA5 codes ETX, DC3, #, 3, C, S, c, and s has a typo in the far left. It should read "0011". In the column containing lower case a, b, c, d..., the top-most character should be a reverse appostrophe (accent) "`"; the reverse slant is wrong. In the extreme right column containing lower case p through z, open brace, etc., the character below the open brace is wrong. That character should be a vertical bar the height of the character space: "|". The slant shown is incorrect. Finally, the definition of EOT is "end of transmission"... just expand the "trans." shown. Oh yes, "(WRU)" is shown in the definition for ENQ. In fact, ENQ has a much broader meaning that the WRU of ITA#2. I would recommend that the reference to WRU here be dropped altogether to avoid confusion in the mind of the reader.

9. p. 14-45, middle column, baud rate. This is a topic that is very easily confused. The top of this column says "a new data-rate specification has been adopted, the baud rate." Firstly, "baud" (used by itself) means 'rate'. The word "rate" is not used in conjunction with the word "baud". More particularly, "baud" is defined by the CCITT to mean the reciprocal of the duration of the shortest signalling element. Because the shortest signalling element is used, the first three entries

in Table 16 are 45.45 baud... but ONLY because ITA#2 teletypewriter codes are transmitted in virtually every transmission system today with ONE pulse (bit) coded into ONE signalling element.

This is NOT necessarily true for ASCII (IA5), especially at the higher speeds. Table 17's left column should be titled "bits per second". But at speeds of 1200 bit/s and higher, the information is usually send using dibit encoding or other related techniques. Each signalling element sent represents 2, 4, 8 or even 16 bits of information. All modems for 9600 bit/s which comply to CCITT standards (found in the Yellow Book, V. series Recommendations) use 4-bit encoding. The shortest signalling element sent by the modem gives a signalling rate of 2400 baud. Since each signalling element represents 4 bits, the information transfer rate is 9600 bit/s. This is the heart of the difference between speed (information transfer rate) and baud (signalling rate). There is a significant benefit to amateurs here. To the extent that the FCC defines limits to ASCII transmission by "baud", we can in fact send higher information rates if we are sufficiently clever to define modulation (signalling) systems to encode more bits on each signalling element... and still survive the rigors of radio transmission without unacceptable error rates.

The wording of this section should be recast slightly to avoid confusion on this point, and to highlight an interesting research area for amateurs.

10. Table 17. Information rates of 150, 600, and 1800 bit/s are not in very wide use and will be dropped from the next ANSI standard covering this subject. I would suggest purging these entries from the Table.

11. p. 14-46: RS-232c. Again, it would be appropriate to refer to the international standard in this section, rather than focusing on our particular domestic standard. The proper CCITT standard here is Recommendation V.24. This is technically equivalent to RS-232c; all of the comments here about RS-232c apply equally well to V.24. V.24 also goes on to specify the connector itself (which is described in detail in International Standard 2110). You may wish to correct the text at the bottom of Table 18 to indication that the 25 pin subminiature D connector is the specified connector for V.24. The column containing circuit references (AA, BA, etc) in this Table should reflect the international circuit designations found in V.24. Furthermore, there is space in this table for an additional column of very important information which is currently missing: the direction each circuit flows. For example, pin 4 (request to send) is sent FROM the terminal. Clear to send is sent TO the terminal. (Please correct the error in the right hand column of text on this page, where it says that clear-to-send is the terminal's signal to the data circuit that the terminal is ready to receive data. Clear to send is actually the signal from the MODEM TO THE TERMINAL that the modem is ready to transmit any information the terminal sends on the transmitted data circuit.)

Other important information which should be included in this section is that V.24 is guaranteed to operate ONLY for signalling rates of less than 20,000 bit/s... and over distances of less than 15 meters.

V.24 interfaces can be made to operate faster or over longer distances, but you are relying on the forgiveness of the signal receivers and the cable characteristics for success in such cases. Also, since the signals are unbalanced, RS-232c/V.24 cabling can radiate lots of hash in the RF spectrum... one reason why the Department of Defense created their own standard in Mil-188.

12. Back to p. 14-45, right column, 'loop circuits', first paragraph, 3rd line from end... I would recommend deleting "and results in what is called half duplex (HDX)," from the text here. It doesn't serve any useful purpose here and can just introduce confusion.

13. p. 14-46, right column, 'other data-connection standards', first paragraph, line 5: I would suggest deleting ", a TTL-compatible interface" which is redundant with the previous line.

14. p. 14-47, left column, 'addition system requirements', paragraph one, next to last line. RTTY "modulator" should be treated the same way as RTTY "demodulator" in the following line; either italicize both or leave both un-italicized.

15. p. 14-47, left column, 'transmission methods', line 7. It says here that FSK is preferred because it gives definite pulses on both mark and space, which is an advantage in printer operation. I fail to understand why this is inherently an advantage in printer operation, other than for the reasons relating to reception outlined in the next sentence. Therefore, I would recommend deleting ", which is an advantage in printer operation"... and at the end of the paragraph change the word "both factors".

16. p. 14-47, left column, frequency-shift keying", end of second paragraph. With the space we just saved above, please insert some information here about which RF signal of an FSK pair is generally considered to be the mark signal. This will parallel the information give for AFSK on VHF in the paragraph above.

17. p. 14-47, right column. Now I am about to suggest some radical surgery. I would suggest deleting ALL the references to ANSI and EIA standards in the bibliography section here. The list, while appropriate to the topics covered in this section, should really be expanded to include international standards if it is to be present at all... and I really can't see a reason why anyone other than a hardware design engineer would find these expensive documents very interesting. If someone is going to delve this deeply into the topic, they will be looking at the specialized communications books available from ARRL and others ... and these references might be more appropriate there. But the four column inches of handbook space might be more appropriately used for other purposes (like more text! or a statement that all readers should work K3NA in the contests! or something like that...)

18. p. 14-48. Firstly, Paul, I support your comment that information on the link level and higher layer procedures we discussed last fall ought to be synthesized into this section. I'll trust you to do your

usual excellent bandwagoning here! ***chuckle***

19. p. 14-48, left column, para 2. "A packet is a group of ASCII characters." A packet can contain anything (as far as bit patterns go -- I wouldn't want to try to send a hamburger in packets...) (Sorry, getting tired and silly.)

Later in this paragraph, about 7 lines from the bottom, "advantages to the packet-controlled board approach" oughtto be "packet-controller" etc.

20. p. 14-48, middle column, end of first paragraph. If the FCS received does not agree with the calculated FCS, the packet is ONLY discarded. The receiver should take NO FURTHER ACTION. Otherwise, receivers for whom the packet was not originally addressed will all be clamoring to get retransmissions of irrelevant packets, and no one will get any information through the system. Error recovery is accomplished by the sender noting the lack of an acknowledgement in a period of time. The station finding a bad packet should not request retransmission...

21. p. 14-48, 'local repeaters'. The term "local area network (LAN)" is introduced here. A more proper industry term is "metropolitan area network (MAN)". Local area nets are restricted to a building or campus. MANs cover a larger area, such as that covered by a packet repeater.

22. Maybe we can sacrifice the following article on the logic translator for more information on networking standards and protocols. Let the logic translator migrate into a specialized handbook....

Regards,

Eric L. Scace
K3NA

Meeting Minutes
Ad Hoc Committee on Amateur Radio Digital Communication
Orlando, Florida
March 8-9, 1983

1) The Ad Hoc Committee on Amateur Radio Digital Communication met in Orlando, FL on March 8 to discuss current packet-radio issues. Present were:

Paul Rinaldo, W4RI, Chairman
Marshall Quiat, AGØX, Alternate Board Liaison
Terry Fox, WB4JFI
Lyle Johnson, WA7GXD
Phil Karn, KA9Q
Wally Linstruth, WA6JPR
Doug Lockhart, VE7APU
Hank Magnuski, KA6M
Harold Price, NK6K

2) FCC PR Docket 85-105 Report and Order

The discussion opened with a synopsis of the situation by Paul Rinaldo. He pointed out that, as written, the restrictions specified in the Report and Order apply to all amateur operations, not just digital modes. Twenty Petitions for Reconsideration have been filed with the FCC.

A primary concern of the Commission is undetected use of the amateur packet-radio network by commercial interests. Harold Price expressed a fear that, since the subject of an audit trail was introduced by the League, the Commission may decide to require such a record for network monitoring. Mr. Rinaldo replied that in talks with the Commission, the point was made that this kind of monitoring would occur without need of a specific FCC-imposed requirement.

President Price, Executive Vice President Sumner and Washington Area Coordinator Williams visited the Commission on February 27 to discuss the subject. The next day, the League filed a Petition for Extraordinary Relief for packet radio above 50 MHz using AX.25 protocol. Harold Price asked whether or not specification of a protocol set a bad precedent. Mr. Lockhart wondered how this affected the users of Vancouver protocols. Mr. Rinaldo said that the FCC had recommended that the petition for relief be as specific as possible and not ask for more than we need to continue operation of the packet-radio network. In addition, specifying AX.25 in the petition would preempt any possible Field Operations Bureau objection that they would be unable to monitor transmissions.

Mr. Fox asked whether or not V-2 could be considered an AX.25-compatible protocol for the purposes of this petition. Mr Quiat recommended against asking the FCC for an interpretation of that question. Mr. Price reminded the Committee that the Commission's expressed concern was with monitoring of amateur packet transmissions, which would be problematic with regard to V-2. Mr. Rinaldo pointed out that it was a practical concern that the FOB be able to (a) read the transmissions and (b) identify the stations in communication, using off-the-shelf TNCs they could buy. Not many TNCs support V-2 (in addition to AX.25) anymore, and it is not possible for FOB to identify the stations as V-2 does not include call signs in the frame header; virtually no one is using CW IDs any more. Mr. Price suggested that the League publish that it was not the League's intent to have the FCC write AX.25 into the permanent rules.

Dr. Magnuski asked whether, in light of the questions of the definition of third-party traffic raised by this action, the Commission should attempt to define by example what is, and what is not, third-party traffic. Mr. Rinaldo replied that, besides being a difficult thing to do, it would be better not to ask the FCC at this time.

2) Congestion Reduction

Mr. Rinaldo reminded the Committee that this subject was discussed at the previous Committee meeting. At the January ARRL Board Meeting, a motion was made that the Digital, VHF/UHF and Membership Services Committees study the existing band plans with an eye toward increasing the spectrum available for packet-radio operation. The Committee members were requested to write to the Chairman with their recommendations, which will be used to draw up recommendations to be forwarded to the other Committees and subsequently to the Board.

Mr. Fox pointed out that the frequencies specified in his paper for the 5th Computer Networking Conference were drawn from discussions with The Middle Atlantic Repeater Council (TMARC). Some of these frequencies were subsequently coordinated for other users. Mr. Linstruth said that frequency coordination was always left to the local coordinators. Mr. Rinaldo replied that we need at least a packet-radio band plan. Mr. Fox asked why not simply state that the available frequencies need to be better utilized. Mr. Price said he thought that the available frequencies are sufficient with proper user education. Mr. Rinaldo asked if that meant that the current 145.0-145.1 MHz band is sufficient. Mr. Johnson pointed out that the use of full-duplex systems was not addressed by specifying that narrow range of frequencies. Mr. Rinaldo replied that the Committee should make it clear that the existing full-duplex repeater pairs may be coordinated for packet use.

Mr. Price suggested that QST articles would help to educate users about frequency usage. Mr. Johnson volunteered to write such an article. Dr. Magnuski pointed out that a capability to monitor the network is essential if the problem is going to be clearly defined, and part of the problem was improper adjustment of equipment, which includes modulation levels and TNC parameters. Mr. Rinaldo wondered if an activity analogous to the "FM clinic" that used to be popular at hamfests would help solve the problem. General approval of that concept was expressed by the Committee. Mr. Price expressed a need for training aids and suggested that the Committee generate a list of such aids for use by local clubs.

In the area of higher-speed packet-radio hardware, Mr. Rinaldo noted that the Committee cannot dictate solutions to industry. Mr. Price stated that the Committee could, however, aid manufacturers by advising them on the market demand for devices. Mr. Rinaldo added that amateurs, particularly TAPR, have already removed some of the risk in manufacturing packet equipment by offering proven designs. By extension, this could be carried over into high-speed modems.

Mr. Rinaldo recapped modem discussions at the Committee's last meeting. Cleary, 9600-bit/s modems are needed. Equally clear is that even higher speeds, eg 56 kbit/s, will be needed soon. While current TNCs will support 9600 bit/s, TNC development will be needed, and must parallel the development of 56-kbit/s modems.

On a related topic, Dr. Magnuski reported on some developments in 9600-bit/s modems that make use of voice-grade channels. Current Rockwell chip sets are priced at $270, but there may be a substantial drop to the $50-100 price range when the modems are integrated into a single chip. Mr. Karn pointed out that this kind of 9600-bit/s scheme would have the advantage of working with an unmodified FM voice radio. Dr. Magnuski will keep the Committee advised of price changes and results of on-air tests.

3) Networking and Transport Protocols

Mr. Karn reported on his Xerox 820 implementation of the ARPANET Internet Protocol Suite, which includes Internet Protocol (IP) with all options, Transport Control Protocol (TCP), User Datagram Protocol (UDP) and a rudimentary Field Transfer Protocol (FTP).

Mr. Fox reported on the implementation of a virtual-circuit networking protocol using a TAPR TNC 2 (or clone) by Howie Goldstein, N2WX.

(Both the datagram and virtual-circuit network-level protocols were demonstrated on March 9.)

Messrs. Karn and Fox were requested to supply more-specific progress reports on these significant developments.

4) Message Transfer Protocol

A message-transfer protocol proposed by Jack Sanders, NC4E had been given to Committee members who attended the last meeting. The the Committee acknowledged that there was some fresh interest in such a protocol for NTS traffic. Mr. Linstruth said that he has sent software to active ARES stations to evaluate and that he was interested in leading the evaluation of this protocol. (Subsequent to the meeting, Mr. Linstruth said that he would work with Mr. Sanders and David Cheek, WA5MWD, who is also interested.)

5) Next Committee Meeting

Mr. Rinaldo asked that the Committee consider a long-weekend meeting in Newington prior to the next Board Meeting. After discussion, the weekend of June 14-16 was selected.

6) Sixth Computer Networking Conference

Conferences 1-5 were:

October 16-17, 1981	Gaithersburg, MD
March 19, 1983	San Francisco, CA
April 15, 1984	Trenton, NJ
March 30, 1985	San Francisco, CA
March 9, 1986	Orlando, FL

Since these Computer Networking Conferences were started, there has been general agreement that they should alternate between the eastern and western parts of the country in order that packeteers would have easy access to at least every other one. In the past, there has always been a hosting organization willing to make the invitation and arrange for local logistics. Also, we have scheduled the Conferences in conjunction with Amateur Radio or computer conventions.

Messrs. Price and Linstruth invited the Committee to consider Southern California as the site of the Sixth Computer Networking Conference sometime in 1987. They will investigate the conventions being held and make a specific invitation after consultation with Southwestern Division Director Heyn.

6) International Issues

Mr. Rinaldo addressed the Committee regarding the need to coordinate with other IARU societies. Those societies already active in packet-radio matters are experiencing problems reconciling existing rules with the potentials of packet radio. Third-party restrictions may prove to be particularly troublesome

in development of international routes. Since the new Board Liaison to the Committee, Tod Olson, is also the ARRL International Affairs Vice President, he has asked for specific recommendations for discussions with other societies. Committee members are requested to contact the Chairman with suggestions.

Jeff Ward, GØ/K8KA, an observer at the meeting, reported on the regulatory problems with packet radio in the UK. In brief, they are: (a) repeaters are strictly controlled in the UK, and there is no allowance for digipeaters; (b) amateur-to-amateur traffic is allowed, but point-to-multipoint transmissions fall under the UK definition of impermissible broadcasting; (c) no 2-meter frequencies are available for packet, and all higher-frequency bands are shared with other services. On the brighter side, interest is high, and meetings are being held to resolve the problems.

7) Data Network Identification Code

Mr. Fox suggested that the League request the FCC to issue a Data Network Identification Code (DNIC) to the Amateur Radio Service. Mr. Rinaldo agreed to raise the question with Perry Williams to research the possibility.

8) Automatic Operation on HF

Mr. Price reported that HF packet traffic was considerably less than it had been because of recent FCC actions. HF station operators are (in accordance with the present rules) taking their stations off the air when not attended. This results in an insufficient number of stations to connect the network at any one time, except perhaps evenings and weekends when most people are off work. He recommended that rule-making action is needed to legalize unattended operation of HF packet stations.

Mr. Karn wondered if a Special Temporary Authority (STA) would serve the purpose for a small number of stations.

(Subsequent to the meeting, Mr. Sumner drafted a paper on an STA approach for possible consideration of the Executive Committee on March 14.)

9) Closing Remarks

Mr. Rinaldo expressed the Committee's appreciation to the people who have worked so hard getting networking-protocol implementations ready for demonstration at the Computer Networking Conference [applause]. He also thanked Gwyn Reedy, W1BEL, and Dick Jansson, WD4FAB, of FADCA, who organized the meeting and Conference [applause]. Jeff Ward rose from the observers' gallery to thank Mr. Quiat for his service as Board Liaison to the Committee [applause].

10) Fifth Amateur Radio Computer Networking Conference

The following day, the Fifth Amateur Radio Computer Networking Conference was held. This event was hosted by the Florida Amateur Digital Communications Association (FADCA). The Conference was held in a room provided in the Expo Centre as part of the Orlando Hamcation and Computer Show. Twenty six technical papers were preprinted in the conference proceedings, which ran 123 pages. Most authors made oral presentations at the conference. We were pleased that Fujio Yamashita, JS1UKR, came from the JARL to personally present his paper. Attendance at any one time was around 75, and interest remained high throughout the day.

Respectfully submitted,

Paul L. Rinaldo, W4RI
Chairman

subject: **Explanation of REC-DRAFT-2** date: **March 16, 1983**

from: **Paul Newland, ad7i**

Recommendation_Explanation

The following is a brief explanation of my thoughts in preparing the attached recommendation. Your comments and suggestions regarding this recommendation will be appreciated.

1,2,3,4: Definition of terms.

5: This insures compatibility between amateur Unshift on Space teleprinters and commercial teleprinters.

6: This encourages standard newline character sequences.

7: Commercial stations, typically, do not use RAST.

8: Electronic terminals should be capable of operating at all common baudrates.

9,10: Because of common usage.

American Radio Relay League Recommendation DRAFT-2
(ARRL REC-DRAFT-2)

The ARRL considering, that for TELEX[1] type radio teleprinter coded communications, it is desirable to:

(a) standardize the terminology of Amateur Radio data communications;

(b) allow for the orderly growth of Amateur Radio data communications;

Recommends, for TELEX radio teleprinter coded communications, that:

1. *BAUDs* be defined to be the inverse of the time in seconds of the smallest signaling element used by a teleprinter to send or receive serial data;

2. *UNSHIFT ON SPACE RECEPTION* (*UOSR*) be defined as an algorithm used by a teleprinter decoder to map a SPACE character to a SPACE and LETTERS sequence and take appropriate action;

3. *RESHIFT AFTER SPACE TRANSMISSION* (*RAST*) be defined as an algorithm used by a teleprinter encoder to transmit either a LETTERS or FIGURES character, as appropriate, following the last SPACE character, of a sequence of SPACE character(s), when the encoder was in the FIGURES case;

4. *NEWLINE SEQUENCE* (*NS*) be defined as a sequence of characters transmitted by a teleprinter encoder when the operator wishes to begin a new line; and that the sequence be as follows: RETURN, LINEFEED, LETTERS (or FIGURES, as appropriate);

5. RAST always be used;

6. the recommended NEWLINE SEQUENCE be used to place following characters on a new line.

7. all Radio Amateur stations be able to engage or disengage, dynamically by convenient operator control, UOSR during communications;

8. all Radio Amateur terminals be capable of communicating at standard speeds of 45.5, 50.0, 56.7, and 74.2 bauds;

9. Radio Amateurs use 45.5 bauds for domestic communications;

10. Radio Amateurs be prepared to use 50.0 bauds for international, intercontinental, communications.

---

1. TELEX, in this case, refers to any of the common 5 unit codes that make use of FIGURES and LETTERS shift characters.

subject: **Explanation of REC-DRAFT-1** date: **March 16, 1983**

from: **Paul Newland, ad7i**

Recommendation Explanation

The following is a brief explanation of my thoughts in preparing the attached recommendation. Your comments and suggestions regarding this recommendation will be appreciated.

1,2: Definition of terms.

3: 1 KHz is chosen so that, initially, narrow bandwidth IF filters are not required for receivers. It is important to note that for narrow shift (or on-off keyed) signals at low data rates using common receivers, channel spacing is determined by receiver selectivity, not transmitter bandwidth.

4: This explicitly sets the origin of channel frequencies to zero.

5: As receivers in the field improve and/or over crowding occurs, channels can be split without impacting the channelization scheme.

6,7: Terms.

8,9 Standard amateur usage.

10: This would resolve problems of using synthesized radios that step in 100 Hz increments. Note that for common amateur tones of 2125 and 2295 Hz (mean = 2210 Hz) the mean is removed from an integer multiple of 100 Hz by only 10 Hz. This should not pose a problem conventional HF data communications.

11: Some commercial systems use RMF higher than RSF, and others do just the opposite. This recommendation insures that amateurs can be compatible with both methods.

American Radio Relay League Recommendation DRAFT-1
(ARRL REC-DRAFT-1)

The ARRL considering, that for High Frequency (HF) low speed Binary Frequency Shift Keyed (BFSK) communications, it is desirable to:

(a) improve spectrum conservation of Amateur Radio communications;

(b) standardize the terminology of Amateur Radio data communications;

(c) allow for the orderly growth of Amateur Radio data communications;

(d) establish channelized data communications by Amateur Radio operators.

Recommends, for HF low speed BFSK communications, that:

1. *CHANNEL FREQUENCY* (*CF*) be defined as the operating frequency;

2. CHANNEL FREQUENCIES be specified in units of Kilo-Hertz;

3. CHANNEL FREQUENCIES be defined to be 1 KHz apart;

4. the first CHANNEL FREQUENCY be defined to be -0- KHz;

5. at some time in the future CHANNEL FREQUENCIES will be defined to be 500 Hz apart;

6. *FREQUENCY SHIFT* (*FS*) be defined as the frequency difference between the MARK and SPACE frequencies;

7. *FREQUENCY DEVIATION* (*FD*) be defined to be one half the FREQUENCY SHIFT;

8. *RADIATED MARK FREQUENCY* (*RMF*) be defined to be the frequency sum of the CHANNEL FREQUENCY and the FREQUENCY DEVIATION;

9. *RADIATED SPACE FREQUENCY* (*RSF*) be defined to be the frequency difference of the CHANNEL FREQUENCY and the FREQUENCY DEVIATION;

10. if audio frequency tones are used to modulate a Single-Side-Band radio to generate BFSK, it is desirable to have the mean audio frequency of those two tones be an integer multiple of 100 Hz.

11. that all Amateur Radio equipment be capable of operating with normal and reverse shift.

-- D R A F T --, pbn, March 16, 1983
The information in this document has not been adopted.
It is subject to change without notice.

THE AMERICAN RADIO RELAY LEAGUE, INC.
HEADQUARTERS SOCIETY OF THE INTERNATIONAL AMATEUR RADIO
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ARRL COMMITTEE ON AMATEUR RADIO DIGITAL COMMUNICATION

March 31, 1983

George Woodward, W1RN
American Radio Relay League
Newington, CT 06111

In re: 1984 Radio Amateur's Handbook Chapter 14

Dear George,

A call was sent out to members of the Digital Communications Committee for suggested changes in the "Radioteletype" section of Chapter 14. Although I have not seen them, I understand that you have comments from committee member, Paul Newland, AD7I. This letter contains the balance of the inputs from the committee, namely comments from Eric Scace, K3NA, and myself.

I have reviewed Eric's suggestions (enclosed) and agree with them with the following comments:

In Eric's paragraph 6, he is correct about ASCII codes from an industry standards point of view. Unfortunately, what governs us is FCC rule 97.69(b)(2) which says that ASCII shall conform to the ANSI Standard X3.4-1968. (That's a fine point in the rules that we should get updated one day.)

The end of the first paragraph under "ASCII" on p.14-43, "As with the Baudot code, the ASCII standard as approved for U.S. amateur use is asynchonous and serial with both start and stop pulses." is incorrect. The August 8, 1978 NOI&FNPRM adopted by the Commission raised such questions how ASCII should be sent. The vast majority of the comments said to leave that to the amateurs. Accordingly, the FCC, in its Third Report and Order on Docket 20777/RM-2429, - 2550, and - 2771 said:

"10. In view of the foregoing discussion, we have decided to amend Section 97.69 of the amateur rules to provide for the use of ASCII in the Amateur Radio Service. The only limitation we are placing on the use of ASCII is a sending speed limit applicable to each band..."

There is nothing there about using asynchronous vs. synchronous or particularly prohibiting parallel ASCII code transmission. The current rules do, however, limit Baudot transmission to "...single channel, five unit (start-stop)..."

In addition to Eric's paragraph 7 comments concerning

Fig. 62, the caption should be revised to say that this diagram is that of an asynchronous ASCII character. It is slightly misleading in illustrating such a long stop pulse. The convention is that a one-unit stop pulse is used for asynchronous ASCII transmissions at speeds of 300 bauds and above. At 110 bauds, a two-unit stop pulse is normal. The diagram could be modified to have a dashed line down the middle of the stop pulse and a note to indicate that one or two may be used, according to the situation.

In Eric's paragraph 10, I dont think that 150 and 600 bits/s should be dropped from this table. See my discussion of data rates in my AX.25 Level 1 draft which proposes to use these rates for hf packets; also, lot's of ASCII equipment can do these rates. Eliminating 1800 is fine. Table 17 doesn't say so, but asynchronous signaling is assumed in this table.

In Eric's paragraph 16 which suggests that you insert something about which rf signal is the mark. I think the paragraph says it at the end. The wording could be clearer.

A few extra words about this paragraph... Steve Lett at the FCC has drafted a rewrite of the "AMTOR" order which will probably make the 900 Hz become 1000 Hz below 50 MHz. It would be well to check this out with Perry Williams before freezing this paragraph. Also, I have a problem accepting the sentence "The smaller values of shift have been shown to have a signal-to-noise-ratio advantage." It's the bandwidth of the mark and space filters that has to do with S/N rather than how far apart they are. I suggest that this sentence be eliminated. Suffice it to say that most Baudot RTTY operators have gone from 850- to 170-Hz shift. (Perhaps what is meant is that the receiver i-f bandwidth can be narrowed -- it doesn't say that.)

In Eric's paragraph 17, he has a point. But I wouldn't go so far as to delete refs to the U.S. standards for now. More of the important international standards references should be included -- if not this year, next.

In Eric's paragraph 21, I suggest that we leave LAN in there for now as the primary term but show MAN as an "also called." He's seeing MAN more in his work arena, mostly with good cause. LAN is a lousy term for a packet-radio network of the kind we have/may have to serve localities. It is burdened by certain definitions such as "on the same campus," "no more than so many km," etc. which are great for coax networks. However, I have two problems with MAN. One is "Metropolitan" means city; how about a localish network serving a rural area? Also, the term is not seen by the average ham anywhere near the times that he will see LAN at the moment. We really haven't found any good terms for the local network or the interconnection of them (internet, WAN [wide area network], backbone, etc.). Let's let this rest and look at it again in a year or so.

In Eric's paragraph 22 he suggests that the logic

translator on pages 14-49 thru -54 be sacrificed for other information. I agree that the space should be pre-empted for new information about packet radio. I'll detail what I think should go in this space later in this letter.

Below are my separate comments:

1. The section caption, "RADIOTELETYPE," is growing a little more awkward with each passing year. Later, starting on p.14-48 there is another equal-rank caption, "PACKET RADIO." In a technical sense, "packet radio" falls under the category of "radioteletype." Note that the FCC, in section 97.69 of the amateur rules calls it "Digital communications," then goes on to say that it could be used for "(but not limited to) radio teleprinter, voice, facsimile, television, communications to control amateur radio stations, models and other objects, transference of computer programs or direct computer-to-computer communications, and communications in various types of data networks (including so-called 'packet switching' systems)." As the pages 14-42 to the end of the chapter need extensive revision, you might consider calling the whole thing "DIGITAL COMMUNICATIONS," then putting "Baudot Radioteletype," "AMTOR," "ASCII," and "Packet Radio" under that.

2. The pages 14-42 through 14-47 have a bias toward the older, Baudot mode. We now have Baudot, ASCII and AMTOR authorized in the latest rules. However, it is reasonable to weight the space allocation to indicate the relative interest in, and development of, each mode. Here's how I think it should be recast:

a. Baudot RTTY is by far the predominant mode now. In editing the existing text, discussion to mechanical TTY machines should be condensed. The machines have been well covered before and are being quickly phased out by RTTYers who can afford to do so. More mention of electronic terminals and use of personal computers to operate RTTY should be sprinkled in. I don't know how justified this is, but I have heard that about 75% of the hf-RTTYers are now using some type computerized terminal.

b. AMTOR is new to most hams. With the exception of the June 1981 QST article, there is nothing available to the average American ham to read about it. I suggest that an AMTOR subsection be added, based on a distillation of G3PLX's article (already mentioned), the League's RM-4122 petition dated May 26, 1982, Micrologand ICS manufacturers' literature, and manuscript material provided by Paul Newland, AD7I. The space for the AMTOR description can be stolen from the logic translator.

c. ASCII code and serial signaling format (as distinct from packet radio) has adequate space. In addition to Eric's comments, there is some inconsistency in whether ASCII has eight information pulses. The middle of the 3rd column of p.14-42 says it has 8, the 1st column of p. 14-45 says it can be anything but

leaves the reader guessing whether any eighth bit must be transmitted. I believe that a review of the FCC Docket 20777 NOI&FNPRM and Third Report and Order, mentioned above, should reveal that the FCC raised the question then never specified that the eighth bit must be transmitted. As things stand, there is very little (non-packet) ASCII transmission on the ham bands. However, ASCII is the native code for most all the terminal equipment in the shack nowadays and deserves adequate treatment.

3. Here are suggestions on enhancing the treatment of packet radio.

a. Early on p.14-48, the reader should be introduced to the concept of protocol layers. This is necessary in order to get away from using the term "packet" where "frame" is clearly indicated. Everything in the 2nd paragraph should refer to "frames" rather than "packets." We're not sending any "packets" yet, until the network layer gets developed.

b. In the 3rd paragraph, the term "Packet Assembler/Disassembler (PAD)" should be introduced as alternative terminology for "Terminal Node Controller (TNC)." The two terms should be shown in Fig. 67.

c. The "Example Packet Transmissions" section and Fig. 66 should be updated to show the changes adopted last October by U.S. packet groups. Namely, the ADR field should be expanded to three. The first is the address of the station called (also called destination address). The second is the address of the calling station (source address). The third is an optional field for the address of a repeater. (Please refer to the papers by Fox [AX.25 Level 2 Protocol] and Magnuski in the proceedings of the 2nd packet conference for details.) If the term "AX.25" is to be used, I suggest that you use it gingerly and only in the sense of an "AX.25 link-level proposal." Although the "AX.25 link-level proposed protocol" is now being implemented by all packet groups that I know of in the U.S., neither the terminology nor the final wording of the link-level protocol document has settled down entirely. I don't know about the degree of Canadian acceptance. The Europeans haven't really come to grips with it yet, although the Swedes (SM5HEV) said that they plan to assure compatibility.

d. There is a problem with Fig. 66. The explanation for SYNC shows the bits **after** NRZI (NRZ-S) encoding. The explanation for FLAG illustrates the bit pattern **before** NRZI encoding. One way of correcting it might be to say that for SYNC, 16 transitions are sent on the radio channel.

e. On page 14-48, 3rd column, "Z-80" is used. It should read "Z80," according to its manufacturer, Zilog.

f. Here and there in the "RADIOTELETYPE" section, the "s" is left off of "baud." Please see QEX 13 for February 1983, p.11, for W2JUP's lesson on "baud" and "bauds."

g. On p.14-49 under "The Wider Network," the acronym "AMNET" should be deleted. We still may end up using this name, but at present it looks doubtful due to the existence of Amnet Inc. of Watertown, MA, which is into packet processors, etc.

h. Also on p.14-49 under "More Information," please change the AMRAD entry to read "... AMRAD Newsletter ($15). William P. Pala, WB4NFB, 5829 Parakeet Drive, Burke, VA 22015. I suggest that you drop the reference to H.A.P.N. because they have not been putting out a newsletter for the past year or so. You should add:

ARRL, QEX: The ARRL Experimenters' Exchange ($6 for ARRL members, $12 nonmembers plus additional postage for overseas).

Tucson Amateur Packet Radio Corporation (TAPR), Packet Status Register, quarterly, ($12). TAPR, P.O. Box 22888, Tucson, AZ 85734.

St. Louis Area Packet Radio Club (SLAPR), SLAPR Protocol ($12). SLAPR, 1309 Gloucester Drive, Edwardsville, IL 62025.

i. The remaining space liberated by the logic translator should be used to summarize the features of the VADCG TNC and the TAPR TNC (Beta test model). Photographs of the W1AW VADCG TNC should be on file. A spec sheet on the VADCG board is in the April 1981 AMRAD Newsletter, which you should have on file. If not, please telephone me on 703-734-0878. I have asked TAPR president, Lyle Johnson, WA7GXD, to provide a similar spec sheet and glossy photo for the TAPR TNC board. I suggest that both of these boards be given a half-page box for both the photo and salient features.

I hope that this is not too much, too late.

73,

Paul L. Rinaldo, W4RI
Chairman

encl. K3NA's Comments
cc: Committee members

Meeting Minutes
Ad Hoc Committee on Amateur Radio Digital Communication
San Francsico
March 30-31, 1983

1) ARRL Fourth Amateur Radio Computer Networking Conference: This event was hosted by Hank Magnuski, KA6M, of the Pacific Packet Radio Society. The conference was held in a room provided at the Moscone Center as part of the Tenth West Coast Computer Faire. Twenty four technical papers (by 26 authors and co-authors) were preprinted in the conference proceedings, which ran 109 pages. Thirteen authors made oral presentations at the conference. Attendance stayed around 100, and interest remained high throughout the entire day of Saturday, March 30. Copies of the proceedings are available from ARRL Hq at $10 each.

2) ARRL Booth at the Computer Faire: The booth was jointly staffed, with the Pacific Packet Radio Society providing much of the coverage. There was a packet-radio demonstration, and ARRL publications were sold at the booth. ARRL book sales, including the proceedings exceeded $2400.

3) WESTNET Meeting: On Saturday, March 30, there was an evening gathering of the packeteers to discuss plans for further development of WESTNET. WESTNET presently connects San Francisco to Southern California via a 2-meter packet-repeater chain operating at 1200 bauds. In order to overcome the congestion now being experienced they agreed to develop a 220-MHz backbone using the 9600-baud modem designed by Steve Goode, K9NG, which was the subject of a paper at the conference earlier that day.

4) Digital Committee Meeting: The digital committee met on Sunday, March 31 at the Hotel Union Square. Present were:

Committee members:

Paul Rinaldo, W4RI (Chairman)
Terry Fox, WB4JFI
Lyle Johnson, WA7GXD
Wally Linstruth, WA6JPR
Doug Lockhart, VE7APU
Hank Magnuski, KA6M
Paul Newland, AD7I

Observers: (partial list)

Phil Anderson, WØXI
Gordon Beattie, N2DSY
Pete Eaton, WB9FLW
Steve Goode, K9NG
Steve Hall, WB6FSK
Phil Karn, KA9Q
Thomas A. Moulton, W2VY
Harold Price, NK6K
Gwyn Reedy, W1BEWL
Bob Richardson, W4UCH
Bob Stricklin, N5BRG
Jeff Ward, K8KA

5) Status of PACSAT: Harold Price briefed the Committee on the results of the recent PACSAT meeting in Arlington, VA.

6) Progress on CCITT X.3, X.28 and X.29 Protocols: At its November, 1984 meeting, Doug Lockhart reported on his work to implement the latest versions of protocols. The Committee showed great interest in these protocols, and requested that Doug prepare a paper for the Fourth Networking Conference and report his progress at this meeting of the Committee. Doug's paper in the printed proceedings, "X.3 and X.28 Protocols for Terminal Node Controllers," is a tutorial on how these protocols work and the advantages of adopting them for amateur packet radio. Briefly, there is a lack of standardization of how an operator talks to a terminal node controller (TNC) and what the TNC says back to the operator. It is a function of the program written into the TNC PROM. Each TNC board producer does it differently. So it is impossible to describe to anyone "how to operate a packet radio" without being specific to the type of TNC and the software written into it. Standardization would not only permit the writing of a standard "how-to" tutorial but would provide facilities that we would need later. As an example, having these standards in place, an application program in a host computer could control the parameters of a distant terminal. The Committee expressed its appreciation for the research that Doug had done and requested that he deliver a draft of a proposed standard to the Committee chairman in early May for editing and circulation to the Committee members. All present were invited to submit comments to Doug as soon as possible so that he may consider them in preparation of the draft. Assuming that all goes on schedule, the proposed draft standard is to be reviewed at the next meeting of the Committee. Harold Price was asked whether he could include X.3/.28 protocols in his next release (version 4.0) of TAPR software, which is due out in the near future. He stated that its incorporation would likely be in version 5.0.

7) Network Protocol Development: This subject has been under intensive discussion since the Committee's September, 1984 meeting. Papers on virtual-circuit (VC) and datagram (DG) networking approaches were presented at the Fourth Conference by Terry Fox and Phil Karn, respectively. Packeteers now seem to be divided into three camps: (1) VC, (2) DG, and (3) DC (don't care -- I wish they'd just quit debating it and write some code that works). At this meeting it was apparent that the DC camp was now in the majority. Progress in writing workable network-layer code (for either VC or DG protocols) has been delayed by the lack of a multiconnection implementation at the link layer. Work under way writing multiconnection software was reported. As soon as this software is completed, the network-layer programmers will have the information they need on interfacing to the link layer.

8) Standardizing Message Protocols: Hank Magnuski reiterated the difficulty he is having moving messages from one network to another because of nonstandardization of formats. Since the last Committee meeting, the WØRLI BBS software, which provides a bulletin board service plus automatic message forwarding between BBSs running the same software, has spread across the country. While the WØRLI approach works and demonstrates a capability, it does not solve many remaining compatibility problems. There appeared to be support for active study of the new CCITT X.400-series messaging protocols with a view to developing a subset that would meet amateur packet-radio needs. Those present were invited to exchange views via DRNET Group 95. (Thanks to Tom Moulton, I now have a copy of the X.400 recommendations for study.)

9) Regulatory Issues: Harold Price raised a number of questions concerning FCC rules.

a) Automatic Control of Digital Communications -- Paul Rinaldo reported that the League's petition, RM-4879, was in the queue at the FCC.

b) Clarifying Legality of Aspects of Packet Radio -- Harold mentioned that there are still some individuals and groups who are not confident about whether packet radio is permitted in the FCC rules. Most of these fears have been dispelled, but there remains some uncertainty whether the repeater call-sign format in the AX.25 frame constitutes a legal repeater ID. After some discussion, it was agreed that the best way of handing this problem would be to prepare something on these issues for the Washington Mailbox column in QST. Paul Rinaldo was asked to pursue this.

c) Expiration of the Teleport STA -- Participants in the teleport STA were asked to report their progress, and Paul Rinaldo was asked to request an extension to the 180-day STA, which is to expire in mid April.

10) Hardware for Network Controller: Lyle Johnson indicated TAPR's willingness to design and produce a "network box." He needs to know the necessary buffer size and numerous other details. Lyle will put a message on DRNET with a strawman of a proposed network controller.

11) HDLC Board for IBM PC: Hank Magnuski recommended that an HDLC board be developed for the IBM PC. Lyle Johnson said that he would consider that as an extension of the network-controller project.

12) Packet Adaptive Modem (PAM): Paul Rinaldo reviewed frustrated attempts getting a pair of stations to test the two PAM boards. Steve Hall, WB6FSK, and Phil Anderson, WØXI, indicated their willingness to run the tests. Both have the necessary HF station and test facilities.

13) Trademarking AX.25: Wally Linstruth recommended that the League trademark "AX.25." The Committee agreed.

14) Next Committee Meeting: After some discussion, it was agreed that the next Committee meeting will be at ARRL Hq the weekend of August 3-4, 1985.

15) Fifth Computer Networking Conference: Gwyn Reedy pitched the Committee on having the next Conference in Florida in early 1986, either at Miami (February) or Orlando (March). The Committee favored Orlando. Gwyn will approach the Orlando Hamcation and Computer Show committee to gain their support and Southeast Division Director Butler for ARRL Board approval.

16) Closing Remarks: There was agreement that the Fourth ARRL Amateur Radio Computer Networking Conference went very well. Hank Magnuski and the Pacific Packet Radio Society were thanked for hosting the Conference. Also, we appreciated the personal efforts of Pacific Division Director Stevens for making hotel arrangements and the time he took to effect local coordinatation. We also expressed our gratitude to Tom Moulton and the New Jersey Institute of Technology for their enthusiastic support of DRNET -- a special electronic mail account used by Committee members and about 15 other key packet-radio experimenters. On behalf of the Pacific Packet Radio Society, Hank Magnuski announced creation of the "Golden Packet" award for establishment of a transcontinental linking of packet-radio repeaters and asked that the enclosed letter be published by the ARRL.

Respectfully submitted,

Paul L. Rinaldo, W4RI
Chairman

Pacific Packet Radio Society
P. O. Box 51562
Palo Alto, CA 94303

March 30th, 1985

Mr. Paul Rinaldo, W4RI
American Radio Relay League
225 Main Street
Newington, Connecticut 06111

Dear Paul:

At the meeting of the Board of Directors of the Pacific Packet Radio Society on March 21st, 1985, the following resolution was passed:

Whereas the Pacific Packet Radio Society was one of the first societies formed specifically to encourage the growth of computer networking via radio using all digital concepts and techniques, and whereas the San Francisco area was the site of the nation's first amateur digipeater, and whereas an even greater challenge faces the amateur radio community to establish a transcontinental link, the Pacific Packet Radio Society has decided to establish a unique award to encourage the completion of the first terrestrial transcontinental network link. This one-time award shall be known as the "Golden Packet" award, and the regulations relating to it are listed below:

1. A transcontinental link must be established, with each terminus located within 100 kilometers of either the Atlantic or Pacific Ocean.

2. The system must consist of fixed terrestrial digital store-and-forward radio links using VHF (greater than 144.1 MHz.), UHF or microwave frequencies. Use of HF, satellite, tropo, metscat or moonbounce channels is prohibited.

3. A valid two-way transmission and acknowledgement of previously unknown information (256 characters or more) must occur in real time (less than ten minutes).

4. This competition is open only to validly licensed North American amateurs, and no commercial links or services may be utilized in the path. Club stations are permitted.

5. Proof of the exchange must be adequately documented and submitted to the PPRS. Proof must include a list of the stations in the link, their locations, frequencies used, and a copy of the text exchanged.

6. The reward shall consist of a suitably engraved plaque with the names of all participating stations listed which shall be presented to the ARRL. Each participating station shall receive either a plaque or a certificate.

7. Final decision on the award is subject to review and approval by the Board of Directors of the Pacific Packet Radio Society.

Respectfully submitted,

H. S. Magnuski

H. S. Magnuski, KA6M

PRNET.PB

Portus Barlow - WA1DCP
30 Park Street
Putnam, CT 06260

Home: 203-928-3654
Work:

Comments: Documentation Manager, PACSAT

PRNET.MB

Mike Brock - WB6HHV
10230 Mayer Circle
San Diego, CA 92126

Home: 619-566-3799
Work: 619-566-5500

Comments: TAPR Beta Site Coordinator, San Diego

PRNET.TC

Dr. Tom Clark - W3IWI
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AMSAT: 301-589-6062

Comments: President, AMSAT

PRNET.DC

Den Connors - KD2S
4708 W. Wild Horse Dr.
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Work:

Comments: TAPR Executive VP, Chairman - TAPR National Organization, AMSAT Asst. VP for Spacecraft Systems; AMSAT - PACSAT Project Manager.

PRNET.PE

Peter Eaton - WB9FLW
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Home: 618-288-5432
Work: same as home

Comments: President, SLAPR, TAPR Beta Site Coordinator

PRNET.TF

Terry L. Fox - WB4JFI
1819 Anderson Road
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Home: 703-
Work: 202-

Comments: AMRAD VP and newsletter editor, Pres. Metrovision ATV club.

PRNET.DLH

Dennis Hanley - KB6C
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Home: 213-881-6667
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Comments:

PRNET.RBH

Randy Hawke - WA6GQR
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Comments:

PRNET.DH

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Comments:

574 0809

PRNET.LJ

Lyle Johnson - WA7GXD
5971 S. Aldorn Dr.
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Work: 602-746-912

Comments: President, TAPR; PACSAT Processor System Group Leader

PRNET.PK

Phil Karn -
61 Breenbrook Road
Berkeley Heights, NJ 07922

Home: 201-322-4724
Work: 201-582-6646

Comments: AMSAT asst. VP, Systems; TAPR Beta Site Coordinator

[illegible]

Larry S. Kayser
85 Helena Avenue
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Home: [illegible]
Work: [illegible]

Comments: PACSAT Memory System Group Leader

[illegible]

Doug Lockhart - VE7APU/3
29 Shamokin Dr.
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Work: 416-443-375

Comments: Past President, VADCG; packet system designer

[illegible]

Hank Magnuski - KA6M
311 Stanford Ave.
Menlo Park, CA 94025

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Work: 415-856-7421

[illegible]

PRNET.DM

Dan Morrison - KV7B
Margaret Morrison - KV7D
4301 East Holmes Street
Tucson, AZ

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Comments: TAPR Central [illegible] Coordinators; Margaret is TAPR Software Coordinat[illegible]

PRNET.HP

Harold Price - NK6K
~~2110 Farrell Avenue #14~~ 1211 FORD AVE.
Redondo Beach, CA 90[illegible]

Home: 213-~~[illegible]~~ 376-3147
Work: [illegible]

Comments: PACSAT Software Manager; TAPR Beta Site [illegible]

[illegible]

Bill Putney - WB6RFW
3557 Golden State Dr.
Santa Clara, CA 95051

Home: 408-246-1636
Work: 40[illegible]

Comments: Patron Saint of PRNET users; Ham of some repute; All Around Good Fellow

Bill Reed - WD0ETZ
~~12963 Amiel Drive~~ 3110 AFTON DR.
~~al[illegible]~~ CARROLLTON TX 75007

Home: 214 492-7508
Work: ~~314 [illegible]~~ 214-241-8011

Comments: PACSAT Ground Station Manager

Paul L. Rinaldo - W4RI
115 Starr Avenue
Newington, CT 06111

Home:
Work: 203-666-1541

Comments: Manager, Technical Dept., ARRL; Chairman, ARRL Digital Communications Committee; AMRAD Director - immediate past president.

PRNET.REW

Ralph Wallio - WORPK
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Indianola, Iowa 50125

Home: 515-961-6406 or 6995
Work: Same as above

Comments: AMSAT Asst VP, Operations

Pat Snyder - WAOTTW
2001 Regnar Avenue
Bowling Green, OH 43402

Home: 612-636-5103

Comments: TAPR PSR Editor; TAPR Beta Site Coordinator

JUDY GORDON

BBN
50 MOULTON ST
CAMBRIDLE MASS

TCP/IP FOR UNIX OPERATION

DAVE CLARK

MIT - LCS

545 TECH SQ

C A VIA C, D, E

TO: HM
FROM: HP
SENT: 25 JUL 83 06:26:02
READ: 01 AUG 83 06:10:38

TO: Hank, Mike.
FM: Harold

Please review and comment.

Preliminary Draft - Not for distribution

NK6K - 7/24/83
WestNet-L2 - An interim level two network using AX.25

This document describes a protocol designed by representatives of the major West Coast (California) packet groups. These groups include:

LAPG (Los Angeles Area Packet Group)
PPRS (Pacific Packet Radio Society)
The San Diego TAPR Beta Test Group
The Ventura/Oxnard TAPR Beta Test Group

The protocol was design with the followings goals in mind:

- Supply a data path from San Diego thru Los Angeles to San Fransisco. Don't worry about the initial speed or thruput of the path.
- The protocol must not require any change to the user level hardware or software, i.e. an "off the shelf" TAPR or VADCG TNC (with AX.25 software) should be able to use the network.
- An obvious precondition to the above, the protocol must not require any changes to the existing AX.25 specification. (But see the fine print below).

The purposes of desisning and building a limited-purpose network at this time are:

- Increase the number of TNCs in this area which can be interconnected. This increases the likelyhood of someone or something being on the air to talk to when a TNC user comes up.
- Provide a reason to acquire mountain top facilities now. Increase use of currently coordinated frequencies to keep from loosing them and to show need for additional frequencies when the next generation network is designed.

The protocol described below meets the goals set and will serve the intended purpose. It is not intended to solve the problems of establishing a large scale nationwide net, nor will it provide a great deal of thruput. It is also not intended to last forever, most of the goals are aimed at reducing the number of "specials" required to implement the net, things that would stand

in the way of the introduction of the level three networks that must come soon. On the other hand, the fact that this network

lives at level two means it will be invisible to level three and can live side by side with it.

The protocol.

It is assumed that readers of this document are familar with the AX.25 specification. The AX.25 spec is available is several places, including the TAPR TNC Users Manual and The Proceedings of the 2nd ARRL Amateur Radio Computer Networking Conference. AMRAD is serving as the official keeper of the AX.25 spec, and copies of it may be obtained from them.

Terms

The following terms are used in the description of the WestNet-L2 protocol.

User TNC. A standard issue TNC running AX.25. User TNCs are the orisination and the destination point for packets in the network.

Network Node. These nodes relay frames between user TNCs. Nodes repeat frames disipeater-style, frames are not acked between nodes, they are acked between user TNCs thrOush nodes. In the first implementation of WestNet-L2,a node is a VADCG TNC running a modified version of the AMRAD AX.25 Disipeater software. A Network Entry Node is usually in hish location or otherwise situated so as to service a large User TNC area and have access to one or more other Network Nodes. Packets sent by Network Nodes are in AX.25 format with additional callsign fields appended to the header. These additional fields are already implemented in all versions of the TAPR AX.25 implementation and in several versions of the AMRAD VADCG AX.25 disipeater software. In general, any Network Node can serve in any of the following roles, the correct role is determined by context.

Network Entry Node. A user TNC directs packets to a specific Network Entry Node to be processed and passed thru the network. A Network Entry Node interprets the network address in the packet and takes the appropriate actions as described later.

Network Relay Node. A Network Relay Node receives packets sent to it from a Network Entry Node or by another Network Relay Node. They are passed to another Network Relay Node or to a Network Exit Node as appropriate.

Network Exit Node. A Network Exit Node takes packets from Network Entry or Network Relay nodes and passes them onto a user

Divide it level two agency it will be invisible to [you] three and can live side by side with it.

It is assumed that programs of this document are familiar with the ANSI specifications. The ed(1) agency is assumed to accept] vicadee, including the DARE TWO (beta Pentax) and The Proceedings of the 32nd ANSI American Design Conference, 1978 (Chicago: American Institute of Architects, 1978). Knowledge of the ANSI agency is not necessary, but a copy may be obtained from them.

The following terms are used in the specification of the Westinghouse protocol.

User TWO. A standard Irvine INC workfile ANSI. User TWOs are the originator and the destination entity for packets in the network.

Packet (packet agency protocol) Packets are not paper bureaucracies, they are video-telephone messages that are sent between TWO (Irvine) workfiles in the network. Packets are in ANSI standard multiprocessor coding file-like envelopes. Packets are used to send and receive messages to one or more other TWOs

TNC. The header of the packet may require modification first, including a possible reversal of the elements of the network address to define the reverse path.

Network address. Up to six alphanumeric characters that take the place of the digipeater callsign in a users connect command and in the packet header. A network address will have a unique SSID field to distiguish it from an explict callsign. The network address specifies either a network exit/entry node pair (implicit routing) or a network path (explict routing).

Node Name. Each Network node is assigned a unique three character identifier. The first character must be alphbetic, the second and third are alphanumeric.

User Domain. A packet which has just been transmitted from a User TNC, or which has been transmitted by a Network Node for reception by a User TNC is in the User Domain.

Network Domain. A packet which has been transmitted by a Network Node for reception by another Network Node is in the Network Domain.

Explicit route. A frame with an explicit route will contain the actual address (callsign) or the network node name of each relay point in the path between the source and the destination.

Implicit route. A user domain frame with an implicit route contains only the network addresses of the Network Entry and Exit points. While in the Network Domain, the frame will also contain the network address of the next node in the path from the current node to the Exit node.

WestNet-L2 Protocol Specification

User Domain Frame Structure

A user domain frame matches the definition specified in AX.25 with the following provision: If a third address subfield is present, and the SSID of the third field is 6, then that address subfield is interpreted as a network address.

Extended User Domain Frame Structure

This frame type is not required for user access to the network, but may be implemented to allow for complete specification of an explict route by a TNC in the user domain. An extended User Domain Frame matches the definition specified in AX.25 with the following extension: The third address subfield is expanded to

an array of "n" subfields called repeater addresses. The low order bit in each byte in all but the nth repeater address is 0. The low order bit in the final byte of the nth repeater address is 1, signalling the end of the extended HDLC address field.

Only one of these repeater addresses can be "active" at any one time. A network node will consider only the active repeater address to determine the current target of the frame. If the repeater addresss to the right of the source address repeater address are considered as an array from 0 to n-1, the repeater address who's index is closest to zero and who's H bit is zero is the active repeater address. If all repeater addresses' H bits are set to one the destination address is considered active.

(destination)(source)(repeater0, H=1)(repeater1, H=0)(repeater2, H=0)

Fig. 1. Extended address - repeater1 is active

Network Domain Frame Structure.

A Network Domain frame has the same structure as the Extended User Domain frame. Network frames with implicit addresses will generally contain two repeater address fields, repeater0 contains the original user-specified network exit/entry pair, repeater1 will contain various other network address as discussed later.

Network address.

All network addresses have an SSID of 6. The network address will interpreted in one of two ways, as an Exit/Entry pair or a Path Name

Exit/Entry pair.

An exit/entry pair is an ordered pair of node names. A node name consists of three characters, the first of which must be alphabetic, the second and third are alphanumeric, none can be spaces. The exit node is always specified first. An exit/entry pair specifies implicit routing. A network node will use the Exit name to determine the next relay address or to decide if it is the Exit point. A network node will use the entry name of the active repeater address field to determine if it is the Entry point.

Path Address.

A Path Address is an ordered pair of Path ID and an entry Node Name. The first character of a path ID must be numeric, the second and third are alphanumeric but not space. The path ID identifies an explicit route in the route tables of the node named in the Entry Node name portion of the field. As discussed later, the entry node generates the explict routing information and places it into the frame's address field. Path IDs are intended for use when an explict route is desired but the number of repeater fields needed to express the route exceed the number of fields the User TNC can generate.

DATA TRANSFER

Entry to the network.

To start a frame on its way thru the network, a user TNC transmitts a frame with an Exit/Entry pair in repeater[0]. No other repeater fields can be present.

Movement within the network.

The action taken by a network node upon receipt of a packet is determined by the contents of the active repeater field. This determines what node is being addressed and what state (Entry, Exit, or Relay) the node should be in.

A node determines if it is the current target of a frame by the following steps:

If the SSID is 6

If the last three bytes in the active repeater field are this nodes ID, then this is the target node.

If the SSID is not 6

If the call sign of this node matches the address in the active repeater field, then this node is the current node.

If none of the above conditions are met, or if there are no active repeater fields, the frame is ignored. A node determines its status (Entry, Exit, Relay) by the following steps:

A Path Address is an ordered pair of Ports to send an entire
Page there. The first Character of a Page is used to route the
Packet. The second and third are Acknowledgement Port
Space. The Path ID identifies an explicit route in the
route tables of the node passed to. More than
one of the Packet, As discussed later, the entire frame
sequences the explicit routing information and passes it
the frame's address fields. Each time the packet reaches
when an explicit route is desired at the number of passes
Packets needed to express the route passed the number of
fields the User Task can generate.

To start a frame on its way thru the network a User
TMC transmits a frame with an Out-of-Range path in
Acknowledgment. As the frame

movement within the network.

The action taken by a network node upon receipt of =
packet is determined by the contents of the entire
Passenger field. This

discussed and what stable Entries Exit or Below the
node should be in.

A node determines if it is the current target of a
frame by the following steps:

If the SSID is A

If the last three notes in the entire
Passenger field are those Nodes It Upon this
is the target node.

If the SSID is not A

If the call area of this node matches the
address in the active Passenger Fields then
the route is

If none of the above conditions are met, or if there
are no active Passenger fields and frame is received,
node determines the status (Entry, Exit, Below) by
following steps:

If the first three bytes in the active address field are also this nodes ID, then this node is the EXIT node. The active repeater field must be the highest numbered field, action taken if higher numbered fields is undefined.

Else if the index of the active repeater field is 0, this node is the ENTRY node. Note that it is possible to be both the entry and the exit node, exit takes precedence.

Otherwise, this node is a relay node.

Actions taken by an Exit Node.

All repeater address fields with an index higher than zero are discarded. Repeater[0] is retained but left marked as has-been-repeater, i.e. inactive. If the address in repeater[0] is an entry/exit pair, the pair is reversed, the entry becomes the exit and the exit becomes the entry, e.g. SFMSCA becomes SCASFM. This will provide the backward path when the destination user TNC responds to the frame.

If the address in repeater[0] is a path address, i.e. the first byte is numeric, the entry node id is replaced by this nodes ID. For example, 001SCA becomes 001SMF.

Once the address transformation has occurred, the packet is transmitted. A user TNC takes action when there are no active repeater fields and the destination address matches the TNCs callsign.

Actions taken by an Entry Node.

The currently active repeater address (repeater[0]) is marked inactive. The appropriate route table is searched based on the contents of the exit node name in repeater[0].

If the exit address in repeater[0] is a Path address:

The Path table is searched for the Path ID. If the path is found, the current frame's address field is expanded by as many repeater address fields as is necessary to contain all the nodes in the path. Each address entry for that path is formed into a relay address with the last three

bytes obtained from the table and the first three bytes set to the Path ID.

If the path is not found, the error state is entered.

If the address in repeater[0] is an exit/entry pair:

The route table is searched. If an entry is found for the exit node, the frame's address is extended make room for repeater[1]. The exit node in repeater[1] is copied from the exit node in repeater[0], the entry node is taken from the table. Repeater[1] is marked active.

If an entry is not found, the error state is entered.

If an error has not been found, the frame is transmitted.

Actions taken by a Relay Node.

If the SSID of the active repeater address is not 6, the H bit is set in that field and the frame is retransmitted.

If the SSID of the current repeater address is 6 and the address is a path address, the H bit is set in the field and the frame is retransmitted.

If the SSID of the active repeater address is 6, and the address is an exit/entry pair, the route table is search for the exit name. If found, the entry name in the active repeater address is replace with the information found in the route table and the frame is retransmitted. The H bit is not set. If no match is found in the route table, the error state is entered.

The Error State

In the first version of WestNet-L2, the error state is undefined. The errored frame is dropped with no further action.

Examples.

In the examples below only the frame address field is presented, with address subfields delimited by '!'. The SSID field is denoted by -n. H0 means H=0 or has not been repeated by this address, H1 means has been repeated by this address.

Invite objects from the table and the 'next hops'
pointers set to the Prefix Tm.

If the path is not found, the error state is
entered.

If the address in message[0] is an exit (whole pair)

The route table is searched. If an entry is found
for the exit route, the frame's address is extended
once room for message[1]. The exit code in
message[1] is copied from the exit route in
message[0]; the entry code is taken from the
table. Message[1] is marked active.

If an entry is not found, the error state is
entered.

If an error has not been found, the frame is
transmitted.

Actions taken by a failed node.

If the SRIP of the active repeater address is not A-
the H bit is set in that field and the frame is
retransmitted.

If the SRIP of the active repeater address = A and
the address is a path address, the H bit is set in the
field and the frame is retransmitted.

If the SRIP of the active repeater address = A and
the address is an equivalency pair, the route [B] is
taken for the exit route. It thereby the entire field in
the active repeater address is replaced with the
information found in the route table and the frame is
retransmitted. The H bit is not set. If an error is
found in the route table the error state is entered.

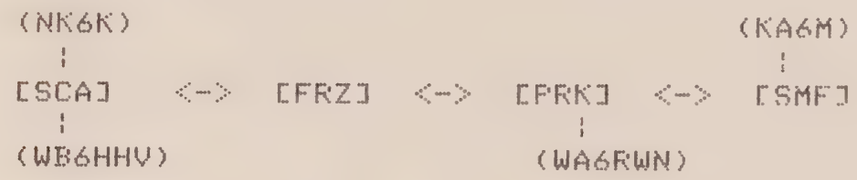
The Error State

In the first version of Datakat-12, the error state is
undefined. The errored frame is processed with no
further action.

Conclusion.

In the examples below only the frame address field is presented.
With address subfields delimited by '.'. The EXIT field is
denoted by '-'. No means NO or has not been received by this
address. H1 means has been received by this address.

The examples assume a physical topology as follows, [] =network and () = user.



SENT BY	FRAME ADDRESS FIELD CONTENTS
NK6K-0	!KA6M-0!NK6K-0!SMFSCA-6,H0!
SCA	!KA6M-0!NK6K-0!SMFSCA-6,H1!SMFFRZ-6,H0!
FRZ	!KA6M-0!NK6K-0!SMFSCA-6,H1!SMFPRK-6,H0!
PRK	!KA6M-0!NK6K-0!SMFSCA-6,H1!SMFSMF-6,H0!
SMF	!KA6M-0!NK6K-0!SCASMF-6,H1!
KA6M-0	!NK6K-0!KA6M-0!SCASMF-6,H0!
SMF	!NK6K-0!KA6M-0!SCASMF-6,H1!SCAPRK-6,H0!
PRK	!NK6K-0!KA6M-0!SCASMF-6,H1!SCAFRZ-6,H0!
FRZ	!NK6K-0!KA6M-0!SCASMF-6,H1!SCASCA-6,H0!
SCA	!NK6K-0!KA6M-0!SMFSCA-6,H1!

SENT BY	FRAME ADDRESS FIELD CONTENTS
WA6RWN-0	!WB6HHV-0!WA6RWN-0!1SDPRK,H0!
PRK	!WB6HHV-0!WA6RWN-0!1SDPRK-6,H1!1SDFRZ-6,H0!1SDSCA-6,H0!
FRZ	!WB6HHV-0!WA6RWN-0!1SDPRK-6,H1!1SDFRZ-6,H1!1SDSCA-6,H0!
SCA	!WB6HHV-0!WA6RWN-0!1SDSCA-6,H1!
WB6HHV-0	!WA6RWN-0!WB6HHV-0!1SDSCA-6,H0!
SCA	!WA6RWN-0!WB6HHV-0!1SDSCA-6,H1!1SDFRZ-6,H0!1SDPRK-6,H0!
FRZ	!WA6RWN-0!WB6HHV-0!1SDSCA-6,H1!1SDFRZ-6,H1!1SDPRK-6,H0!

PRK !WA6RWN-0!WB6HHV-0!1SDPRK-6,H1!

:UDD:HANK:MAIL:ORBIT.ELEMENTS.TUTORIAL 8-OCT-83 22:07:48 PAGE

Posted: Thu Oct 6, 1983 7:49 PM PDT Mss: AGTD-1637-8328
From: PKARN
Subj: Draft of Orbit Element Tutorial

Satellite Orbital Element Tutorial

Phil Karn, KA9Q
Asst VP, Engineering, AMSAT

1. Introductionn

There are several ways to compute motion of a satellite in a uniform gravitational field. Each involves the solution of three second-order differential equations or their equivalent. This models the gravitational force on the satellite (and therefore the acceleration, the second derivative of position) which is a function of the current position. Integrating acceleration over time gives the change in velocity, and integrating velocity over time gives the change in position. The position change "feeds back" into the process, since as the position changes, the acceleration of gravity changes, and as a result the future velocity and position are affected.

You could track a satellite by solving these differential equations brute-force on a computer. To do so, you need to know the "initial conditions," here the starting position and velocity in each of three dimensions, of the satellite at a specified time known as the epoch. These six "constants of integration" are otherwise known as orbital elements. In rectangular (i.e., XYZ) coordinates, this would be the state vector. In other words, if you know where the satellite is and how fast it's moving in a certain direction at a given time, you can predict all future positions and velocities.

2. Two-Body Motion

While this approach is workable, and is often used when forces are present in addition to gravity, e.g., kick motor thrust and atmospheric drag, a given position and velocity isn't very descriptive of the size and shape of the orbit. In addition, direct numerical integration on a computer is slow and prone to accumulated errors when carried on for long periods.

An alternative, the classical Keplerian element set, transforms the state vector into a different set of six numbers. Orbital prediction based on the Keplerian elements is generally much faster and more accurate than brute-force numerical simulation. However, it must be remembered that it is only well suited for the special case of two body motion where the following assumptions are made:

1. The central body (i.e., the earth) is massive with respect to the satellite. This is no problem for artificial satellites, but it means that the moon, which is about 1/80th the mass of the earth, requires modifications to the theory.

2. The central body is perfectly spherical; the force of gravity at any given point in space around the body points directly at the center of the body and depends only on the distance from the center of the body. As we shall see, this is true only to a coarse approximation for the earth.

3. No other perturbing forces (other planets, atmospheric drag, rocket thrust) are present.

The path of a satellite in two-body motion follows a conic section: a circle, ellipse, parabola, hyperbola or straight line. Except for the straight line (which is only a theoretical limit case) all of these orbital paths lie in a fixed plane which contains the center of mass of the central body. The most relevant orbit for our purposes is the ellipse, and the classical Keplerian elements are only properly defined for this case. Since no "real world" orbit is ever PERFECTLY circular, this isn't too serious a restriction. A satellite in elliptical orbit does not stay at a constant distance from the central body; the closest it approaches is called the PERIGEE, and the furthest distance it attains is the APOGEE.

3. The Keplerian Orbitalll Elements

What follows is a list of the classical Keplerian elements and their definitions.

EPOCH TIME, T: While not strictly an "orbital element," a time reference is needed in any element set to indicate an instant at which the remaining numbers are all valid. This number can be chosen arbitrarily by the individual generating the element set, but it is usually chosen somewhere near the middle of the radar or other observation times which were used to generate the elements.

MEAN MOTION, N: the number of complete orbits the satellite makes in one day. The reciprocal of N is the PERIOD, P, the amount of time required to complete one orbit. Also, once the mean motion is known, a quantity called the SEMI MAJOR AXIS, SMA can be computed. This is defined as one-half the straight line distance between the apsides (i.e., the apogee and perigee). Occasionally, the period or SMA will be given

in place of the mean motion.

MEAN ANOMALY, M: An indication of where the satellite is along its orbit at the epoch time. Specifically, it is a measure of time since perigee, expressed as an angular quantity with 360 degrees (one full revolution) being equal to one orbital period. For example, a mean anomaly of zero says that the satellite is at perigee; a mean anomaly of 90 degrees indicates that the satellite is one quarter period past perigee. Another way of looking at mean anomaly is as the time integral of mean motion. (Equivalently, mean motion is the time derivative of mean anomaly.) Since mean motion is a positive constant (excepting drag effects), mean anomaly increases linearly with time.

It must be emphasized that since a satellite in an elliptical orbit does NOT move at a constant rate, the "angle" represented by the mean anomaly does not correspond to any measurable, physical angle. However, knowing the mean anomaly and the eccentricity (described below), you can compute the TRUE ANOMALY, v, which is the angle as seen from the center of the earth between the perigee point and the satellite's current position, measured in the direction of satellite motion. Likewise, knowing the true anomaly and the eccentricity, you can compute the mean anomaly.

ECCENTRICITY, e: the degree of "lopsideness" of the orbit. e = 0 would be a perfect circle; 0 < e < 1 is an ellipse, e = 1 is a parabola, and e > 1 is a hyperbola.

Now we have determined the size and shape of the orbit. Next we need to specify how the egg-shaped orbital ellipse is rotated within its orbital plane with respect to an external reference.

ARGUMENT OF PERIGEE,, w: the angle, as seen from the center of the earth and measured in the orbit plane in the direction of motion of the satellite, between the equator and the perigee point. An argument of perigee between 0 and 180 degrees indicates that apogee occurs in the Southern hemisphere; a value between 180 and 360 degrees represents an apogee in the Northern hemisphere.

Next, the orbital plane must be oriented with respect to an external reference frame. Two numbers are needed to do this:

INCLINATION, i: the angle between the orbit plane and the earth's equator. An inclination of zero means that the

models do exist.

satellite is always above the equator; an inclination of 90 degrees indicates that the satellite passes over both poles

on each orbit.

RIGHT ASCENSION OF ASCENDING NODE, RAAN or capital-omega: the angle, measured along the equator, between the First Point of Aries (a reference celestial longitude) and the point on the orbit plane where the satellite crosses the equator going northward. The First Point of Aries is defined as the point at which the Sun crosses the equator into the Northern Hemisphere at the first instant of Spring. Right ascension is necessary here because it is fixed in space; longitude measurements would depend on the position of the rotating earth.

4. Perturbations

If one assumes perfect two-body motion, implying the absence of external perturbations such as the non-spherical shape of the earth, gravitational tugs from the moon and sun, thrust, atmospheric drag, etc, all of the above elements except for mean anomaly would remain constant for all time. Of course, the real world isn't so ideal, but several of these effects are easily compensated for.

The most important factor for most satellites is the non-spherical shape of the earth. This causes both short-term and long term changes in the argument of perigee and right ascension of the ascending node.

Additionally, for low altitude satellites, drag can be an appreciable factor. The first factor is easily computed from the other orbital elements; the second can be at best only approximated. The DRAG FACTOR, N-dot/2, indicates the rate of orbital decay by its effect on the mean motion, N. A drag-free orbit has a constant N; atmospheric drag will remove energy from the satellite and increase its mean motion at the rate of 2*N-dot revolutions per day per day. Of course, as the satellite drops into a lower orbit, atmospheric drag will increase. Therefore predictions based on just a single drag term are at best approximations.

Effects of solar and lunar perturbations can usually be ignored for low altitude satellites. More sophisticated models do exist, however, which take into account these

effects and they are very useful in the operational planning of geostationary satellites.

For further readings into the details of orbital mechanics and prediction, I would recommend the following to start:

+ Tom Clark, W3IWI, "Basic Orbits," ORBIT magazine #6. This describes Tom's now-famous orbital prediction program written in BASIC that has been adapted to many different personal computers. Disk or cassette copies of this program are available from AMSAT for a nominal donation; write for details.

+ Bate et al, "Introduction to Astrodynamics," Dover, $6.50. This excellent paperback is designed for a college level introduction into the subject. Included are sections on orbital element generation which I used in the determination of Oscar-10's orbit after the kick motor burn.

73 and good luck,
Phil Karn, KA9Q

This is a combination tutorial on data transmission and progress report on the PACSAT modem design project.

I have been fortunate to recruit a fellow Bell Labs employee, Ed Shrum, W2IKI, to assist with this project. Ed works at the Holmdel lab about an hour south of here and we keep in touch mainly by electronic mail and an occasional eyeball when he comes here (Murray Hill) for other business. Ed plans on attending the AMSAT general meeting and also the Oscar-10 ground command station meeting assuming schedules permit. He is very interested in becoming an AMSAT "hard core" contributor and is beginning to do quite a bit of work.

So far he has constructed a prototype BPSK modem using switched capacitor loop filters (the MF-10), essentially combining my ideas for selectable speed with W1HDX's GOES BPSK Costas Loop design. He is about to start testing on this unit once he finishes a test PSK transmitter and gathers the appropriate equipment (like a bit error rate analyzer.)

As far as turning this effort into usable modems, I do not anticipate any major changes to the design once the usual testing and fine tuning is completed. At that point it could be turned into a PC layout (if someone is willing to volunteer for this job) and mass produced. It will be usable for the AO-10 GB, the UoSAT-B beacon, and as a terrestrial packet radio modem. In summary, to build a complete BPSK modem for either PACSAT, AMICON or terrestrial use, you will need three boards:

1. A Costas loop BPSK demod (the board we're designing.) This board will also contain the necessary baseband filtering hardware for the PSK transmitter.

2. A front end capable of turning whatever RF you are using into IF. The ONLY frequency determining component on the entire demodulator is the VCO coil; by winding a different number of turns you could accommodate any IF in the HF range (e.g., 3.395, 10.7, etc.) For our purposes we are using Hamtronics 70cm/10m converters and changing the crystals for 10.7 mhz output (Hamtronics doesn't make a 70cm/10.7 mhz converter any more.) I have bought and assembled two at $49.95 each.

3. A linear transmitting converter on the appropriate band with a wideband input mixer. This seems to be the rule rather than the exception. I have bought and assembled two Hamtronics 10m/70cm 1 watt transmitting converters for this purpose. This particular converter is fairly conventional in design: an oscillator chain generates an injection signal 28 mhz below the intended RF frequency and feeds it to one port of a SBL-1 wideband balanced mixer. The 10 m drive signal is fed via a resistive attenuator to the IF port of the mixer. The RF signal appears at the third port of the mixer and is fed through a linear amplifier chain to the output.

It struck me very early while working with these modules that it would be very easy to simplify the transmitter design as follows. Retune the oscillator chain to produce a signal ON the output frequency (rather than 28 mhz below.) Remove the resistive attenuator designed to pad down a 10m SSB transmitter. Now drive the converter with lowpass filtered data from your TNC or whatever and voila! out comes BPSK. Very little extra hardware, no images to worry about.

In contrast to Ed, who has been doing all the actual soldering, I have been spending most of my time recently boning up on all the signal and filtering theory that I either should have learned in school (when there wasn't any real incentive to learn it) or learned once and forgot.

My goal here is to design the optimal filters for both the transmitter and the demodulator arms to minimize the RF bandwidth and maximize the bit error rate performance of the system. I have been assuming that the DPLLs in the HDLC chips will do receive clock recovery (as they do now) so in addition the zero crossings of the received data stream should be reasonably jitter free.

At this point I go into tutorial mode, so you can skip the rest if you don't care about all the gory details of signal theory and filter design, etc.

Transmit Bandwidth Limitation

The FCC rules on digital communications (assuming we don't want to deal with STAs) define occupied bandwidth as "the width of the frequency band, outside of which the mean power of any emission is attenuated by at least 26 decibels below the mean power of the total emission; a 3 khz sampling bandwidth being used by the FCC in making this determination." (97.69 (3) (c) (2)) On 2 meters, this bandwidth has to be less than 20 khz.

If we assume that they mean the power contained in ALL frequencies outside the passband should add to less than 26 db down from the in-band signal components, this means that we have to have less than 0.25% of the total transmitter power outside of the bandwidth limits. To be polite to our amateur neighbors (particularly for a terrestrial link where the signal levels might be quite strong) we should do better than this if we can, particularly for components well removed from the main signal.

The ideal spectral shape for a signal such as ours would be rectangular in shape, i.e., be entirely contained within a specified bandwidth. The Fourier Transform of a square pulse is a sinc (sin(x)/x) waveform; conversely, the Fourier transform of a sinc waveform is a square pulse. Unfortunately, the sinc function extends off to infinity in both directions. If we run the output of a TAPR board directly into our PSK modulator, the resulting power spectrum will have this sin(x)/x shape (actually a sin-squared(x)/(x^2) shape) and extend over quite a bandwidth. I simulated this on a computer using randomly-generated data; the resulting spectrum has sharp nulls at 1x, 2x, 3x, etc., the bit rate on each side of the carrier and spectral peaks between each pair of nulls. The peak of the lobe between 1x and 2x the bit rate was only about 9db below the main lobe; all the way out at lobe #16 it was only down to about 25 db. Hence the case for filtering.

One way to get a good cutoff would be to signal with sinc pulses instead of square pulses. In the ideal case the spectrum would fall off to nothing instantaneously, but the time-domain pulses would have to extend off to infinity in both directions! In fact, if you were to signal with impulses (rather than square pulses) and use an "ideal" low pass filter, this is what you would get.

Ignoring for the moment how you generate the signal over all time, it is alright to send sequential bits consisting of summed, shifted sinc pulses and still be able to separate them at the receiver SO LONG AS the bandwidth represented by the Fourier transform of the sinc pulses is no less than 1/2 the bit rate. E.g., if you're sending 10 kilobits/sec, the required baseband bandwidth would be at least 5 khz. Since this applies only for the baseband signal, you have to double this for BPSK since it is essentially double-

sideband AM, complete with two mirror-image sidebands. I.e., the minimum RF bandwidth would then be 10 khz, or a "spectral efficiency" of 1 bit per second per hertz.

This is just the Nyquist sampling theorem in reverse. This is the one that says that in order to digitally record and reproduce an audio signal you have to sample at a minimum of twice the highest frequency component. For example, to reproduce 20 khz you have to sample at at least 40 khz. Here, however, the 2:1 rate/bandwidth ratio is in our favor.

A problem comes here when you want to recover the data clock. The preceding analysis assumed that you already had perfect knowledge of when to sample the demodulated data stream at the receiver; the sinc waves (due to bandwidth limiting) add and cancel in all kinds of funny ways between each bit, but assuming that the bandwidth is wide enough for the bit rate there will be an instant in the middle of the bit interval at which the sinc pulse components from the adjacent bits (the "intersymbol interference") all go to zero and allow us to accurately sample the current bit.

You can see this with an "eye pattern" on a scope which monitors the recovered baseband data at the demodulator output. Sync the scope to trigger at some submultiple of the bit rate and run random data through the system. On the scope you will see all of the various bit sequences overlapped, but there will be empty space in the middle of each bit interval (the "eye opening".) The point at which this opening is the widest vertically is the point at which you sample the signal and decide whether a 1 or a 0 was received.

Since we can't exactly use atomic clocks at each of our decoders to determine this magic sampling instant, we will have to recover clock from the data stream itself and this will require some more bandwidth. One way is to transmit a bit framing sequence at the beginning of each packet and phase lock a bit clock which will then "free-run" through the rest of the frame, generating sample pulses for the demodulator. I haven't investigated this approach fully, but it has the disadvantage of extra complexity and requires that we toss the "free" DPLL in the HDLC chips.

In order to do things the "easy" way (i.e, let the HDLC chip do all the bit timing), it is necessary that not only do the bit centers come through without inter-symbol interference, but also the transitions between each bit. This is equivalent to "sampling" the data stream twice as fast and therefore requires twice as much bandwidth. Now we're up to 20 khz for our 10 kbps signal. Interestingly enough, this corresponds to the first spectral null in the unfiltered BPSK signal. All we have to do is lop off the extra redundant side lobes and we're done.

There are several ways to do this filtering. Clearly, whatever method is used will be easier to do as lowpass filtering on the baseband signal before BPSK modulation than as bandpass filtering on the modulator output; this allows the use of audio (including active op-amp and switched capacitor) filters instead of requiring passive RF (e.g., crystal) filters.

Whenever a pulse signal is filtered, we would like that all of the frequency components of the signal that do make it past the filter do so with an equal propagation delay. The term for this is "constant group delay". Since group delay is the derivative of the phase response (the shape of the phase shift vs frequency curve)

another term for this characteristic is "linear phase."

Unfortunately, the analog filters that have the fastest amplitude rolloff in the frequency domain (desirable to get rid of the extra sidelobes) are also the ones that have the worst group delay response. The effect is to smear the pulses in time such that the eye opening closes, reducing the system's tolerance to noise. If the eye opening closes completely, you get errors even in the absence of noise. Since the group delay distortion is greatest near cutoff, you can minimize its effect by making the filter wider than it has to be, but this obviously offsets the only advantage of the filter which was its faster rolloff.

Digital filtering is one way to construct sharp cutoff filters that also have good group delay response. In particular, the FIR (finite impulse response) filter can always be constructed in such a way as to GUARANTEE linear phase (and flat group delay). The FIR filter has been around for a long time, before digital filtering, under a different name: transversal equalizer. The basic idea is simple: you run your signal down a delay line. At regular intervals along this line, taps sample the signal as it propagates. Each tap feeds an amplifier with a proscribed gain (the "tap coefficient") and the outputs of all the amplifiers are summed. This becomes the output of the filter.

For an ideal low pass response, the delay line would have to be infinitely long and the tap gains would follow a sinc (sin(x)/x) pattern. It turns out, however, that linear programming methods very similar in principle to the algorithms I used for least-squares fitting of orbital elements to ranging data on Oscar-10 can be used to determine the optimum (you get to define "optimum") tap gains to be used in a real (i.e., finite length delay line) filter. The finite length of this delay line is what gives the filter its name.

For example, with a 32-tap delay line, you can get low pass filters which fall reasonably fast to zero response outside the passband and then have stopband response ripples with a maximum amplitude of -50 db, obviously sufficient for our purposes. If you want faster cutoff at the expense of somewhat higher ripple in the stopband, you can get this too. Faster response AND lower ripples require more taps.

Unfortunately, delay line implementations of FIR filters are impractical for our needs, and software implementations on conventional microprocessors are much too slow. There are a number of digital signal processor chips around (e.g., the Intel 2920.) While it is most likely unsuitable for spacecraft use (NMOS and EPROM!), it might conceivably be useful on the ground; unfortunately even it may not be fast enough for our use.

The Bell Labs DSP chip is considerably faster than the 2920 but it is both very expensive and not yet available outside the company. The whole idea of using DSPs in our modems is promising, but it needs further study and is probably not practical in the short term.

Since the use of an FIR filter for transmit signal filtering is actually a rather degenerate case, it might be possible to synthesize the response of such a system through the use of a ROM look-up table and D/A converter. This approach also needs further study to evaluate the complexity tradeoffs. One particular case I have looked at is putting a sine wave into the ROM, driving a D/A converter with the ROM and addressing the ROM with a counter that is ramped up and down between its limits for each bit. This method works quite well; the peak sidelobe amplitude outside the main one is down perhaps 30+ db.

an amplifier
output
of the

Which brings us back to the topic of analog (i.e., simple) filtering. Actually, there is a filter which has quite good group delay characteristics: the "Bessel" filter. Unfortunately, it also has terrible amplitude roll-off response.

There are other filters with varying degrees of tradeoff; to quantitatively evaluate each type, I spent quite some time writing programs to simulate sending a random data sequence through each type. One program produced an eye pattern; another simulated the whole PSK system, complete with random white noise being added to the "channel" and the bit error rate performance recorded. (It's great having all this spare CPU capacity at night!) In my next installment I will summarize the results of these models and determine what kind of filter we can use and what the likely performance will be as compared to ideal BPSK.

73, Phil

AMSAT OSCAR-10 Frequency Conversion Chart

(Revised 9/8/83)

Revised Mode B Frequency Guide*

(Exclusive of Doppler Shift)

Uplink (LSB)		Downlink (USB)	
		145.987	Engineering Beacon
435.0323	Scheduled Use	145.9720	SSC H1
435.0423	Scheduled Use	145.9620	SSC H2
435.0447		145.9600	GCB Upper Limit
435.0477		145.9570	ACNF
435.050		145.955	
.055		.950	
.060		.945	
.065		.940	
.070		.935	
.075		.930	SSB
.080		.925	
.085		.920	
.090		.915	
.095		.910	
.100		.905	
435.1037	Center Band	145.901	MIXED
.105		.900	
.110		.895	
.115		.890	
.120		.885	
.125		.880	— RTTY CALLING
.130		.875	
.135		.870	CW
.140		.865	
.145		.860	
.150		.855	
.155		.850	
.160		.845	GCB Lower Limit
435.1647	Scheduled Use	145.8400	SSC L2
435.1747	Scheduled Use	145.8300	SSC L1
		145.810	General Beacon

*Based on conversion frequency of 581.0047 MHz.
SSC — Special Service Channel
GCB — General Communications Band
ACNF — AMSAT Calling and Net Frequency

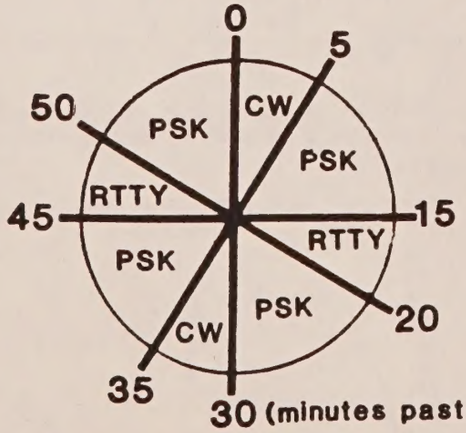
Preliminary Mode L Frequency Guide*

(Exclusive of Doppler Shift)

Uplink		Downlink	
1269.050		436.950	Upper Limit
.075		.925	
.100		.900	
.125		.875	
.150		.850	
.175		.825	
.200		.800	
.225		.775	
.250		.750	
.275		.725	
.300		.700	
.325		.675	
.350		.650	
.375		.625	
.400		.600	
.425		.575	
1269.450	Center Band	436.550	
.475		.525	
.500		.500	
.525		.475	
.550		.450	
.575		.425	
.600		.400	
.625		.375	
.650		.350	
.675		.325	
.700		.300	
.725		.275	
.750		.250	
.775		.225	
.800		.200	
.825		.175	
1269.850		435.150	Lower Limit
		436.040	Engineering Beacon
		436.020	General Beacon

*Based on a translation frequency of 1706.00 MHz, estimated.

General Beacon Operating Schedule For AO-10

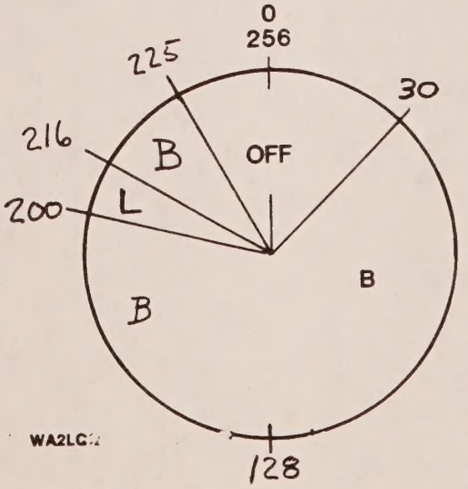


Effective August 84

WA2LQQ JUL 84

AO-10 Transponder Schedule

2/1/86 → MARCH 86

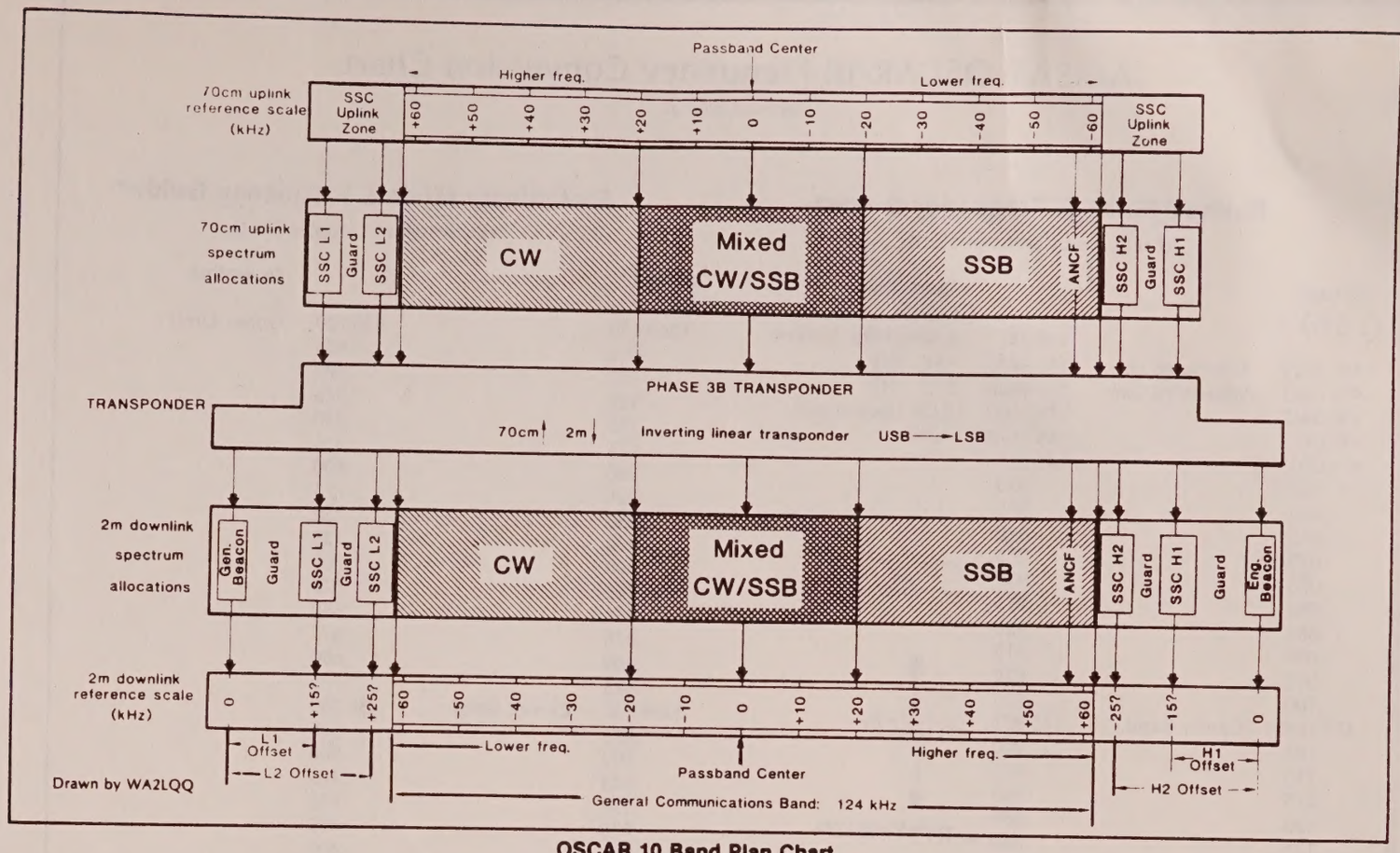


Numbers refer to Mean Anomaly. Perigee equals 000. Apogee equals 128. To convert to minutes of time multiply by 2.732.

CHECK 145.810 BEACON FOR UPDATES!

UTC	EDT	EST
0000*	2000	1900
0100	2100	2000
0200	2200	2100
0300	2300	2200
0400	0000*	2300
0500	0100	0000*
0600	0200	0100
0700	0300	0200
0800	0400	0300
0900	0500	0400
1000	0600	0500
1100	0700	0600
1200	0800	0700
1300	0900	0800
1400	1000	0900
1500	1100	1000
1600	1200	1100
1700	1300	1200
1800	1400	1300
1900	1500	1400
2000	1600	1500
2100	1700	1600
2200	1800	1700
2300	1900	1800
2400*	2000	1900

CHARTS COURTESY OF AMATEUR SATELLITE REPORT



OSCAR 10 Band Plan Chart

INFORMATION NET SCHEDULE

NET NAME	DAY/TIME (UTC)	FREQ. (MHz)	NOTES
AMSAT Espanol	Sunday 1900	14.180	
AMSAT International	unday 1800	21.280	
AMSAT International	Sunday 1900	14.282	
AMSAT European 20m	Saturday 1000	14.280	
AMSAT UK 80m	Sunday	3.780	1015 Local Time Sunday
AMSAT Asia/Pacific	Sunday 1100	14.305	
AMSAT South Pacific	Saturday 2200	28.878	
AMSAT South Africa	Sunday 0900	14.280	
AMSAT South Africa	Sunday 0900	7.080	
SEASAT	Sunday 1300	7.280	
East Coast 75m	Wednesday	3.850	2100 Local Time Tuesday
Mid-American 75m	Wednesday	3.850	2100 Local Time Tuesday
West Coast 75m	Wednesday	3.850	2000 Local Time Tuesday
Australian AMSAT	Sunday 1000	3.680	
New Zealand V.U.S.	Wednesday 0800	3.850	
VHF NETS			
New York City 2m	Wednesday	144.400	2200 Local Time Tuesday
AMSAT Goddard	Wednesday	146.835	2100 Local Time Tuesday
Los Angeles 2m	Wednesday	144.144	2000 Local Time Tuesday
Los Angeles 2m	Daily	144.144	0730 Local Time Tuesday
AMSAT South Africa	Sunday 0900	145.650	
AMSAT UK 2m	Sunday	144.280	1930 Local Time Sunday

Time Conversion Chart

Time zone	EST	EDT	CST	CDT	MST	MDT	PST	PDT	AK/HI ST	AK/HI DT
Time difference	5	4	6	5	7	6	8	7	10	9

To convert from UTC to _____ (time zone) subtract _____ (time difference) hours.

To convert from _____ (time zone) to UTC add _____ (time difference) hours.

This table may be used to convert from day/month notation to the day of year notation often used in satellite scheduling and computer programing.

Month	*Day of year = day of month + number listed* (regular year)	(leap year)
January	0	0
February	31	31
March	59	60
April	90	91
May	120	121
June	151	152
July	181	182
August	212	213
September	243	244
October	273	274
November	304	305
December	334	335

CHARTS COURTESY OF AMATEUR SATELLITE REPORT